THE SCIENTIFIC TEMPERANCE HAND-BOOK

F. R. CHESHIRE F.L.S., F.R.M.S.

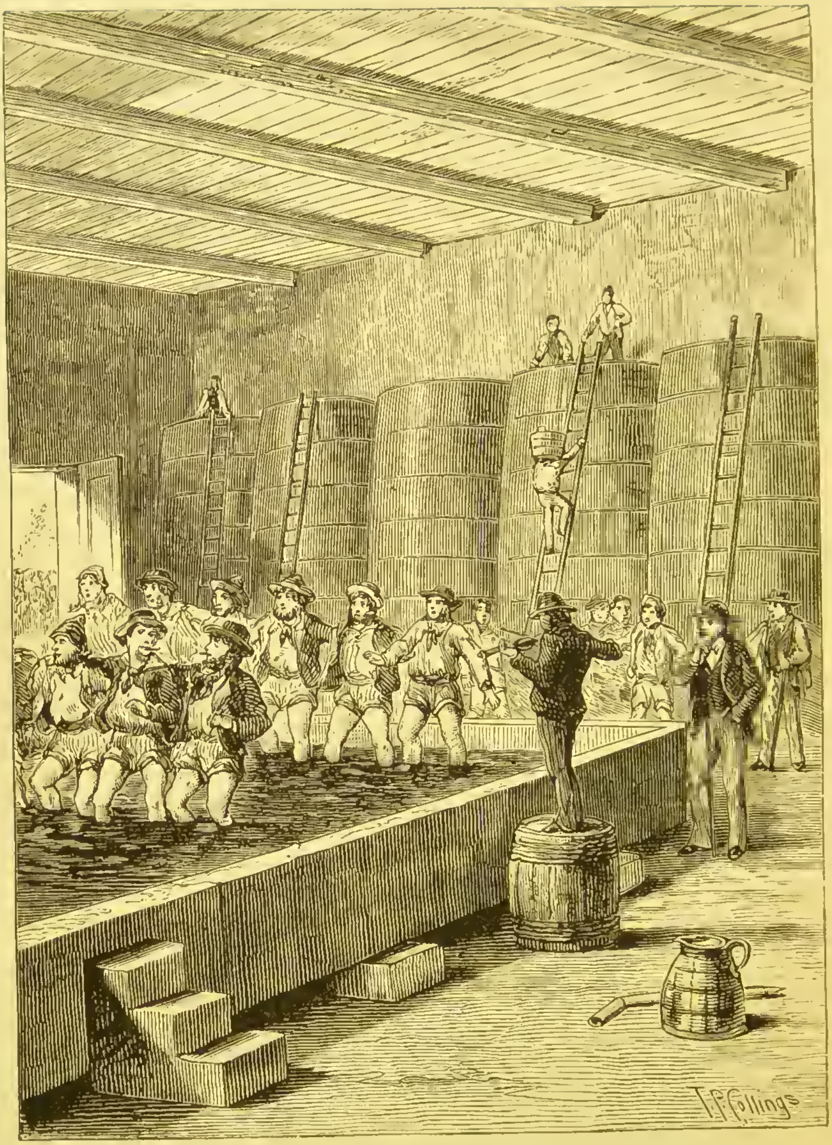

FIG. 27.—TREADING GRAPES IN THE LAGAR IN MAKING PORT WINE.

[*See page* 88.

THE

SCIENTIFIC TEMPERANCE HAND-BOOK.

FOR TEMPERANCE TEACHERS AND ADVOCATES,

AND

FOR SENIOR CLASSES IN SCHOOLS.

BY

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"THE APPARATUS FOR DIFFERENTIATING THE SEXES IN WASPS AND BEES,"
"THE RELATIONS OF INSECTS TO FLOWERING PLANTS,"
"THE ANATOMY OF THE HIVE BEE," ETC., ETC.

WITH

Numerous Illustrations and Original Experiments

AND

360 QUESTIONS FOR EXAMINATION.

LONDON
NATIONAL TEMPERANCE PUBLICATION DEPOT,
33 PATERNOSTER ROW, E.C.

EDINBURGH:
PRINTED BY LORIMER AND GILLIES,
31 ST. ANDREW SQUARE.

PREFACE.

The literature of the Temperance question is already very extensive, and yet, up to the present time, no book (so far as the author's knowledge reaches), has made its appearance which covers the ground this one is intended to occupy. Those authors dealing scientifically with the action of alcohol have, for the most part, either given a compilation of opinion enforced mainly on the ground of authority, or have been hampered in their explanations by realising that these supposed scientific knowledge which their readers would only occasionally possess. The author, in order to obviate as far as practicable the latter difficulty, has dared to face the criticism that he has written a temperance book, which is not all on temperance, by giving a section on "Science for Total Abstainers," in which he has endeavoured to make a firm, scientific basis for the leading lines of argument contained in the rest of the book. As the latter is studied, the importance of, or rather the necessity for, the first section will become the more evident, yet those having some science training may commence their study at the second section, turning to the first at a subsequent opportunity.

The author during a prolonged career as a lecturer has noticed that authority alone is very nearly valueless. To the greater number the opinion of one man is as good as that of another, and where these conflict, inclination gives the casting vote. He, therefore, has striven to supply facts, and their logic, to appeal to the understanding more than the memory, and to secure the conviction of his reader by leading him to an irresistible conclusion.

Where this book may be used for class work in schools, the intelligent teacher will supply explanatory comment, in which he will receive much suggestion by the plan of page references given with the questions for examination.

The author, with deep pleasure, expresses his indebtedness to his son, Mr. Horace Cheshire, F.C.S., who has placed at his disposal that close acquaintance with the chemistry of the question which he has acquired during the prosecution of his profession as borough analyist, and to another kinsman, Mr. H. Mainwaring, A.I.A., who has furnished valuable particulars respecting alcohol and mortality, he gratefully returns thanks.

Finally, he covets for this effort the encouragement former ones have received, so that it at least may contribute somewhat to the furtherance of that great Cause which is beginning to be accepted as the true basis of national reform.

FRANK R. CHESHIRE.

"Quinton,"
Bromley, Kent.

CONTENTS.

SECTION I.—SCIENCE FOR TOTAL ABSTAINERS.

SECTION II.—INTOXICATING DRINKS.

SECTION III.—ALCOHOL AND THE BODY.

SECTION IV.—ALCOHOL AND THE NATION.

THE

SCIENTIFIC TEMPERANCE HAND-BOOK.

SECTION I.

SCIENCE FOR TOTAL ABSTAINERS.

CHAPTER I.

The Air we Breathe.

THE main object of this book is to put in a clear light the sad injury to health and the terrible poverty, disgrace, and misery too often produced by intoxicating drinks, so that its younger readers at least, forewarned against the cause of so much mischief, and led by all that is good and true, may live wisely and happily, and do their best towards bringing happiness to others.

But, in addition, many related matters will receive some attention, such as the preservation of our health, the management of home, the choosing of our food, the need of pure water and fresh air, the necessity for cleanliness, and much besides; and in order to understand these clearly, we must learn something about the beautiful

world in which God has placed us, the composition of the air we breathe, the nature of the plants we eat, the structure of our wonderful bodies, and the way in which they act, as well as a little about trade and money, so that we may see how much poorer beers, wines, and spirits have made, not only our own country, but almost every other.

When we wish to build up a house that shall be solid and strong, the first part of our work must be hidden from view, for we have to dig down in order to lay our foundation, which has to carry all that we place upon it; so here we must appear for a time almost to forget the questions relating to intoxicating drinks, in order that the knowledge may be gained upon which future arguments must rest.

Our first lesson, then, will be on the air which, as our breath, supports our life minute by minute, and, like a great ocean, surrounds us on all sides, and reaches many miles above our heads, and in which the birds fly much as the fish swim in the water, while we walk about on the earth's surface after the style of the crabs and lobster that always crawl at the bottom.

In a usual way we do not see the air, because it is so transparent, that is, it lets the light go through it even much more easily than the light goes through the window-pane. But the air *can* be seen, and a little experiment will help us to understand why. When the clothes are rinsed after washing, blue is put into the water. This

makes the white clothes that are deep down in the tub appear dark blue, but the clothes that are near the top look almost white, while, if we were to paint with this blue water, we should not see any colour at all. The air is blue like the water we have been talking about, but it is so very, very pale, that we can only see the colour when we look through a great deal of it.

Some of us do not get an opportunity of seeing mountains. Such must be content with a picture showing some naturally coloured. Either way, we shall find them and other distant parts blue, because the great amount of air between us and them makes them blue like the clothes deep down in the tub, while with things that are near to us we cannot see the colour of the air any more than we can see blue when we paint with the blue water. When we look up, if there are no clouds, we say the sky is blue, but the blue is really the colour of the great mass of air through which we are gazing. It is not quite known how the colour is produced, but most likely it is due to solid particles which the air carries in it, and about which we have a great deal to learn in Chapter VII. and some others.

But if it is difficult to understand how we can see the air, we can always easily feel it, and hear it too, for, to do this, we have only to blow from our mouths into the palms of our hands ; and let us remember that by the air striking in different ways upon our ears we hear one another's voices, and

every note of music to which we have ever listened. While the sense of smell very much depends upon the air carrying different odours to our noses.

It is worthy of our attention that the air is itself quite without odour, so that substances possessing a smell can be detected at once. We are thus frequently made aware of the presence of dangerous bodies by the nose. For example, the poisonous coal gas, if allowed to escape unburnt, is at once known by its smell. If any substance about our houses begins to putrify, it would become a source of danger to health, but its nasty odour reveals it, and should lead to its immediate removal. The most delicate and delicious perfumes can be enjoyed in all their purity, because the air which carries them is absolutely odourless. It is almost equally important that the air is without taste. The same negative qualities are found in water, and the wisdom of Providence is shown in giving to the two most universally present bodies (air and water) neither colour, taste, nor smell. If water, which forms three-quarters of the bodies of animals and vegetables, were red or blue, what would be the effect? Imagine the result of coloured rain, or the influence on flavours of water of strong taste. And this apparently small matter will be seen to be of the highest value to the beauty of nature, and to our health and comfort.

When the air is all moving along, we say the

wind blows, and how beautifully it holds up the kite when the string is pulled against it; but, if it is going quickly, what force it has! How it will slam doors and turn umbrellas inside out! But we must not think that it can only do mischief. The wind is continually taking away bad air and bringing fresh, carrying the clouds, that have been formed over the sea, across the land where the rain is wanted, and doing us good in all sorts of ways; besides its force is often made to do very useful work, to turn mills, called wind-mills, and to drive our ships across the ocean, often even helping the steamer, and so saving a great deal of coal.

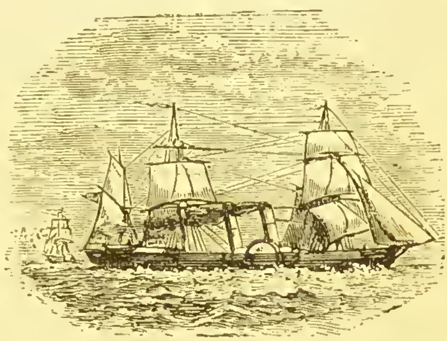

Fig. 1.—Steamship.

When we consider that we can walk about in the air, while it is still, without noticing it at all, it seems strange that it can sometimes have such power — blowing up the sea into terrible waves; tearing up great trees by the roots; unroofing houses, and suddenly destroying the strongest works of man; but we shall understand it, if we think of the weight of the air. It is certainly light compared with water, which weighs nearly 800 times as much.* A box

* The relation between the density of water and air is undergoing constant small variations, according to the dampness or

one foot every way (a cubic foot), holds about $1\frac{1}{4}$ oz. of air, but 1000 oz. = $62\frac{1}{2}$ lbs. of water, as fig. 2 shows. Yet when we have large amounts of air, the weight becomes considerable. Let us take a school class-room which is 60 feet long, 20 feet wide, and 15 feet high, then multiplying all these together, it will give us 18,000 cubic feet, which would weigh 1416 lbs., nearly three-quarters of a ton. Even an ordinary railway carriage of five compartments holds air weighing not less than 70 lbs. How tremendous, then, must be the weight of the

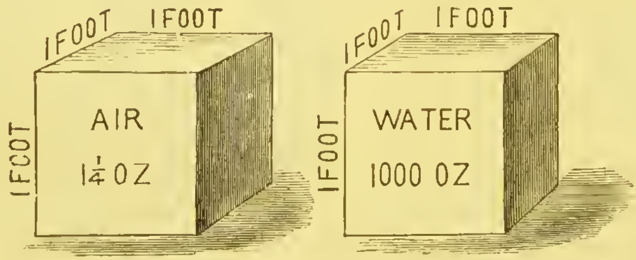

FIG. 2.—RELATIVE WEIGHT OF AIR AND WATER.

whole air covering round the globe, and reaching far above the highest mountains. It is easy to prove that it is as great as would be that of a ball of lead 66 miles from side to side, and that it presses upon every square inch of surface with a force equal to 15 lbs. Now we can see that a large bulk of air rolling rapidly along, must have surprising force.

dryness of the latter, temperature and pressure. Water at the freezing point, with the barometer at 30 in., is exactly 773 times the density of air, but 800 is easily remembered, and is sufficiently accurate for practical purposes.

When air gets warmer, it expands or occupies more space, or, as we should say of solids, it swells, and then a cubic foot of it does not weigh so much as $1\frac{1}{4}$ oz. Take a tumbler (*t*, fig. 3) three-fourths full of water, and put into it a glass bulb and tube *b* (an oil-flask, neck downwards, would do nearly as well). Now heat the bulb, and, as the air within gets warm, it will expand, and some of it will escape in bubbles as shown in the figure. When we take away the lamp, the air, which is left in the bulb or oil-flask, cools and contracts to its former size, and then water is pressed up the tube into the bulb to supply the place of that which has bubbled away. If three pints of air at the ordinary temperature (heat) of a dwelling-room be made as hot as boiling water, they will become four pints, or the same three pints would expand to between twelve and twenty pints in the heat of a furnace. As hot air thus becomes lighter, the heavier cold air pushes it up so that it rises. This is why the fire balloon, which gives so much fun, goes up. The hot air is pushed up, and it takes the balloon along with it. It is the reason also that the air in the chimney, when the fire is burning, ascends, and the heavier cold air coming in through every little crack, keeps our rooms ventilated and healthy, as we shall have more particularly to learn in

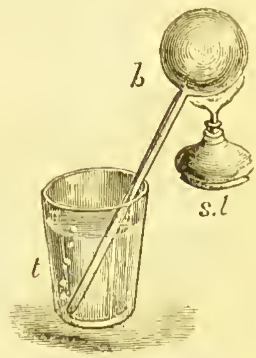

FIG. 3.—AIR EXPANDS BY HEAT.

another chapter. We now see why balloons rise when filled with a very light gas, called hydrogen, or by coal gas, both of which are even much lighter than the air, which pushes them up, by its greater weight.

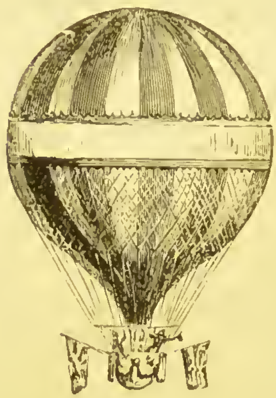

FIG. 4.—GAS BALLOON.

Where air is, other bodies cannot come—*e.g.*, filling a narrow-necked bottle needs a steady stream so that as the liquid flows down, there may be room left for the air to flow up through the neck. Pouring too quickly stops the escape of the air which then prevents the fluid entering so that it flows over sputtering and gurgling as the air bubbles through it. Similarly if we put a tumbler, mouth downwards (*a*, fig. 5), into water, the air will keep the inside dry, but by tilting the tumbler as at *b*, some of the air will escape in bubbles, and the water will enter, taking its place. Could we use hydrogen gas in this experiment, instead of air, it would give us just the same result, for the air consists of gases, but about these we shall have to talk in the next chapter.

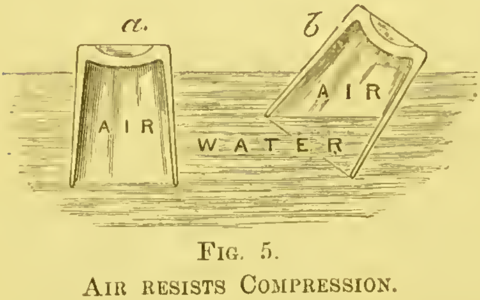

FIG. 5.
AIR RESISTS COMPRESSION.

The tumbler acts exactly like a diver's helmet (fig. 6), which is a metal case surrounding the head, but open below where it rests on the shoulders. Wearing this and a water-tight dress, the diver can work and breathe without being wetted. He looks through glass plates protected by metal strips, for if these glass plates were to be broken the air would escape, allowing the water to flow in, when most likely the poor man would be drowned. While by a pipe (*a*), air is supplied to him from a pump, the impure air, which he has breathed, escapes in bubbles below his helmet. Were this constant supply to fail he would quickly die, as our breath acts as a poison to us, as we shall see more clearly hereafter. He carries a rope (*b*) in his hand by which he communicates with his attendants. His work is dangerous, notwithstanding every care, so his pay, as it should be, is rather high.

FIG. 6.—THE DIVER.
a. Air Tube; *b.* Guide Rope.

CHAPTER II.

The Chemistry of the Air and Combustion.

We have already learned some of the properties of the air; it has no smell and no taste, yet we can feel it, hear it, and even, in some cases, see it. Now we have to consider that of which the air is made. We remember that hydrogen and air act in exactly the same way in the tumbler, pressed down into water (see fig. 5), and that hydrogen is a gas—for coal gas, which is burnt in the street lamps and in the shops, is an impure kind of hydrogen. This prepares us to learn that air is a gas also; for any substance that floats about in space and that will take up room for itself, as the air in the tumbler did, is a gas. Really, the air is made up of three kinds of gas, mixed together. And it is the chemist who has found out quite a number of different gases, who has to tell us what these are, and how one can be divided from the other. He has named those of the air nitrogen gas, oxygen gas, and carbonic acid gas. Of the first there is the greatest quantity, and of the last very little indeed.

If we turn on the gas tap, we hear a hissing sound,

like that made by blowing air through a small tube, and soon we notice a disagreeable smell; but, if the gas be lighted, it burns, and we get no smell, although we know large quantities of it must have escaped into the room. While the gas burns it gives us light, because it is uniting with one of the gases of the air, called oxygen, and then becomes so exceedingly hot that it can be seen. If a cold poker be taken into a dark room, it is invisible, but, if the poker be red hot, it will give a light sufficient to see to read, although none of us would like a red hot poker for a lamp. So with the gas, before it is lighted it only escapes and *mixes* with the air, remaining cold, when we cannot see it; but, when it burns, it joins with the oxygen, and both become so hot at the time of combining, that they give out light, and we can see them as we can see a red hot poker in the dark. From this we learn what flame is. It is the appearance of gases uniting at a very great heat.

Now we try an experiment with a candle. The candle is lighted and we watch, but nothing is seen to leave it, and yet the candle is disappearing—it is losing weight continually; or, as it has been drolly remarked, "The longer it burns the shorter it grows." The candle is clearly going somewhere; it cannot be changed into nothing. It is really passing away into the air and being so altered that we cannot any longer see it. But by blowing upon the flame so as to put out the candle, we at once see a thick smoke rising from the wick, and notice that it has a sickening

smell. Quickly bringing a lighted match near to the smoke,* it catches fire even at an inch from the wick, and as the flame travels along to relight the candle the smoke vanishes. From this it is plain that the tallow, by being made very hot in the wick, is converted into a thick smoke, which as it flames becomes invisible. Let us now try to understand the meaning of what we have observed.

The fat of which the candle is made consists principally of two kinds† of matter; one is our old friend, the gas hydrogen, and the other is called carbon.‡ Carbon by itself is a solid black body, and is the cause of the sootiness of the smoke that rose from the smouldering wick, and as the carbon as well as the hydrogen unites with the oxygen of the air, we may write down the chemical change thus—

$$\text{Candle} = \begin{cases} \textbf{Hydrogen.} \\ \textbf{Carbon.} \end{cases}$$

$$\begin{matrix}\textbf{Burnt} \\ \textbf{Candle}\end{matrix} = \begin{cases} \textbf{Hydrogen and Oxygen.} \\ \textbf{Carbon and Oxygen.} \end{cases}$$

* The experiment will not succeed well with a paraffin candle. It needs a tallow dip, or, better still, several thin tapers twisted up together. With these a train of six inches of smoke can easily be burnt.

† There is also some oxygen in tallow, but this is now omitted to simplify the explanation.

‡ If we take a piece of bread to toast and heat it too much, we drive away some of the material of the bread, and the carbon remaining by itself is black, as already explained. Paper, or wood, or flannel, when scorched, all become black for the same reason; thus carbon forms part of tallow, bread, paper, wood, and flannel.

Experiment.—Write or draw on paper with very weak sulphuric acid (12 water to 1 acid), nothing will be seen till the paper is held before the fire or over a lamp, when the sulphuric acid will separate the hydrogen and oxygen and leave the carbon, so that the writing or drawing will suddenly appear perfectly black.

Let us first think of what is formed when the hydrogen and oxygen are united together. You would hardly suppose it to be water, but such is true. The flame of gas, of candle, of lamp, of furnace, all alike give out innocent, cooling, fire-destroying water, but when the water is formed it is of course very hot, and so escapes above the flame as invisible vapour, but we can soon make it show itself by another of those little simple experiments we should never omit to try, until we quite understand what they mean. Take a bright knife, or better still the bright knob of a poker, and pass it rather slowly through a flame, and it will get covered with moisture which we can now wipe off with our finger and which just before had been separate hydrogen and oxygen. Or better, take a bell glass (fig. 7) or wide mouthed large bottle, and hold over the flame of a candle, and soon the water will begin to trickle down inside. The glass must not be held too low or the heat may break it.

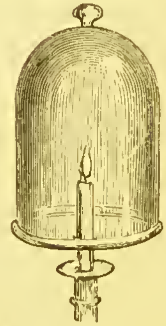

Fig. 7.—Water from Flame.

The carbon, the other part of the candle, next

requires our attention, and a further experiment is needed to show that the carbon is there. We take a flat sheet of paper (*s.p.*, fig. 8) or a small piece of window glass, and pass it backwards and forwards through the flame, and we find dark sooty stains are made upon it. These consist of carbon, such as we a while before saw in the dark smoke, and which has been separated from some of the hydrogen of the tallow in the following manner. Hydrogen has such wonderful power in seizing hold of oxygen that it gets its share first, and in so doing in large measure, deserts the carbon its former companion, which for a moment is left almost alone.

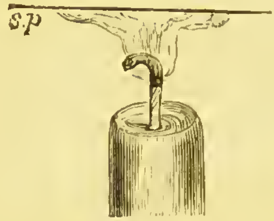

FIG. 8.—SOOT FROM TALLOW.

When the candle is burning in the usual way, the partially separated carbon very quickly combines with a further supply of oxygen, which, as part of the air, is flowing past the flame, but by our sheet of paper we hinder the process by delaying the passage of air, and so catch the carbon as soot before it is burnt.

Removing our paper, nothing that we can see escapes, because, as shown by a previous experiment, the carbon is uniting with oxygen. By so doing it forms an invisible but heavy and poisonous gas called carbonic acid gas. This floats about in and mixes up with the air, just as the vapour does that is produced by the burning hydrogen. That the carbon does become invisible

we can easily observe by burning a piece of charcoal, when it, by combining with the oxygen, appears to dissolve away leaving scarcely anything behind. We can now write these changes in fuller form, thus :—

$$\text{Burnt Candle} = \begin{cases} \text{Hydrogen and Oxygen} = \text{Water.} \\ \text{Carbon and Oxygen} = \text{Carbonic Acid Gas.} \end{cases}$$

We have already said that air consists of three kinds of gas mixed together, but we have only yet spoken of the oxygen, because it is the one that causes the candle, the gas, the oil lamp, or the fire to burn. But although oxygen does so much, it is only about one-fifth part of the whole : nearly all the rest is nitrogen, which will not unite with burning substances at all, and takes no part in the changes we have been studying except to most usefully hinder them, for if no nitrogen were present and oxygen made up the whole air, bodies would burn so violently that we could not control them, and indeed if under these circumstances we were to light a fire in the stove, the stove would no sooner get hot than it would burn along with and just as well as the coals.

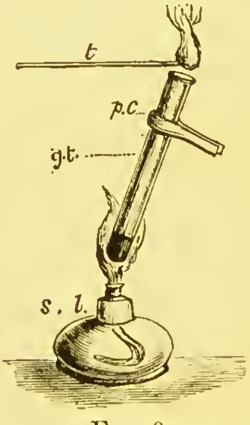

Fig. 9.
Oxygen Making.

We can easily try how things would burn in oxygen as follows: Take a thin glass tube (*g.t.*, fig. 9) about 6 in. long and from ½ to ¾ in. wide,

and put into it one or two thimblefuls of "oxygen composition,"* which gives out a considerable quantity of oxygen when made hot. Make a paper clip (*p.c.*) by folding a half sheet of note paper into a band, which place round the tube as in the figure, and by this hold the tube in the flame of a spirit lamp (*s.l.*). Ignite a common wax taper (*t*), and so soon as the oxygen begins to rise in the tube place the flame at the mouth of it. The flame will become small, but exceedingly bright, while the taper will burn away very rapidly. Now remove the taper and blow out the flame, returning the glowing wick to the oxygen, when it immediately relights. This may be repeated any number of times till the oxygen is exhausted.

Why did the taper burn so vividly, and why did it relight when only glowing? Here is an explanation. Suppose a box of white beads to be upset, and you had to pick up a hundred, you could do it quite quickly; but if there were four times as many black beads as white ones all mixed together, then picking up the hundred white ones would take much longer. So with the taper when burning in the common air; it can only slowly pick up its oxygen, because four times as much nitrogen is mixed with it. It is hindered by the nitrogen as you would be hindered by the black beads,

* This consists of two parts Potassic Chlorate, one part Manganese Binoxide pounded together. It can be bought, prepared, of the practical chemist at about 6d. per lb.

but when we put the taper into oxygen it picks up all that comes to it, and it burns quickly, and gives out a great deal of heat and light. If we blow the taper out, the wick smoulders like a piece of glowing charcoal because its carbon is slowly uniting with oxygen, while the hydrogen and some carbon go off unburnt in the smoke. When we bring the wick to the pure oxygen the carbon of the wick glows so intensely that it gets hot enough to relight the hydrogen, and then we have flame but no smoke. If we look now at fig. 10 we shall see the whole thing quite clearly, and notice that the oxygen of the air is used up by the burning candle, but that the nitrogen remains.

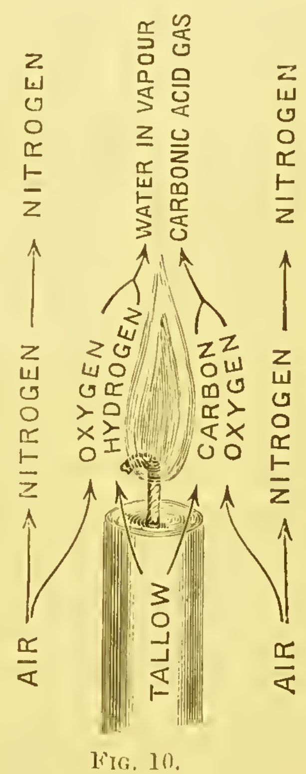

FIG. 10.

Carbonic acid is the third gas found in the air. It is plain now, how it gets there. Carbon by burning forms it, and animals, and we ourselves during the whole of life are producing it, and pouring it out in our breath, yet the amount good air contains is very small, only about one part in two thousand five hundred, but in crowded rooms, or where many lights are burning, there

will be a good deal more of it unless the ventilation is very perfect. Carbonic acid gas is a most important gas as it is the food of plants (see Chapter V.), yet more than the very small quantity just mentioned is unwholesome, and every effort should be made in our homes to secure such a continual change of air that the amount of carbonic acid is kept small. A large excess very quickly causes headache and drowsiness, while, if it increase to one twenty-fifth of the whole air it rapidly destroys life.

The lesson we are now concluding is very important, as it is essential in understanding the use of our breath, and the way in which we are kept warm, for we really, though not burning with a flame like lamps or candles, are passing through exactly the same changes, and are constantly in part being converted into water and carbonic acid gas.

By-and-by we shall see that, while oxygen is our good friend, enabling us to keep up our heat, and put out strength, and think clearly, intoxicating drinks deprive us of its services in proportion to the amount taken, while they increase the quantity of carbonic acid gas in our blood, and so make us heavy and dull and unfit for work, either of body or mind.

CHAPTER III.

Chemistry of Water.

Our last lesson showed that when bodies combine they become entirely changed. The coal gas that smells so badly loses all smell when it unites with oxygen in burning. The candles that can be weighed in a scale, and that are greasy to our touch and have a peculiar odour, in uniting with oxygen in burning, become vapour of water and carbonic acid gas floating about us in an invisible form, as much unlike candles or tallow as they could possibly be. Other changes quite as curious will come to our minds—*e.g.*, if a bright knife be left in a damp place it will become reddish brown, will have lost its hardness, and we can scrape it into powder, because oxygen from the air and water have united with the iron and formed a *new body* quite unlike either of the things that went to make it. We call the new body rust. It, as shown by what we have already said, is composed of iron, oxygen, and hydrogen. Pink copper in a damp place becomes green because it combines with oxygen, hydrogen, and carbon from the air; while, from a

similar cause, brass which is cleaned till it shines like gold in the morning, may be dull and dirty brown at night.

So wonderful and so varied are these changes that all the material of our earth, and most probably those in the moon and planets, sun and stars also, are made out of less than seventy different and distinct kinds of matter. Many of these are so very rare that it is certain that by far the larger number of the readers of these chapters have never yet seen more than thirty-five of them; and further, all the trees, plants, flowers, and fruits, and the bodies of all insects, birds, beasts, and fishes, include only about fourteen different kinds, the great multitude of appearances presented by all forms of life, whether vegetable or animal, being produced by the various ways in which these few distinct kinds of matter are united together.

Those substances that contain only one of these kinds of matter are called elements, those that contain more than one are called compounds. Water, from what we have already learned, is a compound, so is carbonic acid gas, the first made of the elements oxygen and hydrogen, the second of the elements carbon and oxygen. Brass is a compound metal made of zinc and copper melted together, but zinc and copper are both elements because neither of them can be divided into two kinds of matter. We must say then that there are less than seventy elements; only thirty-five

are at all common, and all plants and animals together only embrace fourteen.

Every *element* and every kind of substance is made up of tiny particles, called *atoms*, and these are so exceedingly small that if they were hundreds of thousands of times larger than they are, with no microscope could we ever see them, and our minds must certainly fail in trying to imagine their littleness, but I will give you a proportion which will surprise you more and more as you think of it. *As the size of the great world on which we live is to the size of a raindrop, so is the raindrop to an atom.*

All the atoms making up a quantity of any element are exactly alike—*e.g.*, all hydrogen atoms are of the same size and weight, and have the same way of acting. All oxygen atoms are also like to one another, but they do not resemble those of hydrogen in that they act quite differently, they may be a little larger and we know they are sixteen times as heavy. Again all the atoms of iron are alike, but they act in a different way from oxygen or hydrogen, while they are fifty-six times as heavy as the latter.

Saying, then, that there are about seventy distinct kinds of matter is but another way of saying there are about seventy different kinds of atoms. And these it must be remembered never change. They combine, and then totally different substances are produced, but when they separate again they are exactly what they were before. The atoms never wear out. The

heat of a furnace does not affect them. Their properties continue unaltered from age to age. My younger readers will wonder how all this can be known if the atoms are so minute that no eye can see them, but at present it is quite impossible for them to understand how it has been made clear, but by reading and thought they may have the pleasure of conquering the difficulty when older.

The unions or combinations we have been talking about in which the bodies that are joined change so curiously, are called *chemical* unions, and these are quite unlike mere mixing. If we put milk and water together, they mix, but the milk remains milk, and its taste is unchanged, and even if much water is mixed with little milk, after a time some cream will come to the top. We can mix any quantity of milk with any quantity of water, but if we have a chemical union, exact quantities only will unite. Thus, in producing water, two pints of hydrogen will combine with exactly one pint of oxygen, no more, no less. We shall see the reason of this as we learn that in chemical unions it is the atoms of the one substance which join with the atoms of the other.

We may mix a heap of hooks with another heap of eyes, and there may be any number we please in each heap, but if the hooks are really to be joined to the eyes, we must have the same number of each. Four hundred and fifty hooks cannot join with four hundred eyes, fifty of the hooks must be left over. If we are to make

skipping-ropes we must use exactly twice as many handles as pieces of rope. If we have more than twice as many, the excess must be left unused. Again, in the chair factory, we may see stacks of seats and backs and piles of legs, the manufacturer does not know how many of each he has, but if he is to use them all up in making chairs he must have four times as many legs as backs or seats, otherwise some parts must remain over and be so far useless. So in chemical unions *exact quantities only* will unite.

In the production of water by burning gas or tallow, two atoms of hydrogen and one of oxygen join together. The oxygen atom grasps a hydrogen atom on each side of it, and if we put **H**, as chemists always do, to represent an atom of hydrogen and **O** an atom of oxygen, we might picture the way in which they combine as follows, although we must not suppose that they are arranged in such straight lines :—

(H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H)
(H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H)
(H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H)
(H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H) (H-O-H)

Here we see each oxygen atom with its two companion hydrogen atoms, like the skipping-rope with its two handles, which shows that we must have twice as many hydrogens as oxygens.

This, and the next two or three chemical questions which follow, are rather difficult, for

like almost everything that is worth learning, they require that we should use our minds earnestly, but all who really persevere to understand them will find them a wonderful help, and already we must be beginning to get delight from noticing that in this beautiful world, which our mistakes and misdeeds has often made so wretched, every tiny atom always seems to know its duty, and falls into its proper place so accurately and uniformly that we can certainly predict what will happen when substances that have been studied are put together.

Very likely you see a difficulty. Hydrogen is very, very light, 14½ times lighter than the air. Oxygen is very little heavier than the air, yet water, formed from these, is nearly 800 times as heavy as air (see fig. 2). How *can* light gases form it? It is because in gases there are great spaces between the particles, but something very curious happens. Atoms seem as though they disliked to be alone, and so, in most gases, they join together in pairs, and, as before we pictured water, so now we can picture hydrogen gas, with its atoms joined two by two, and great spaces between them.

(H-H) **(H-H)** **(H-H)**

(H-H) **(H-H)**

(H-H) **(H-H)** **(H-H)**

When atoms combine together we must have a word to express their condition. It is Mole-

cule; pronounced in three syllables, Mo-le-cule. (**H-H**) is a molecule of hydrogen, (**O=O**) is a molecule of oxygen, and (**H-O-H**) is a molecule of water. In water, the molecules are near together (see page 31), and so the water is heavy.

A very clever Italian* long since discovered that, under similar conditions, all gases contain the same number of molecules in the same space or volume—*e.g.*, a pint of hydrogen contains as many molecules as a pint of oxygen, and since each pint contains twice as many atoms as molecules, it follows that a pint or any similar measure of each will contain the same number of atoms. Therefore, twice as much by measure of hydrogen will be required as of oxygen to form water.

The great spaces between the molecules that form gases can be seen from what follows. 1696 measures of hydrogen with 848 measures of oxygen give us 2544 measures of mixed gases (see fig. 11), but if these be lighted and combined one measure only of water results. Still that one measure weighs as much as the far greater bulk of gases. At the time of union, a tremendous explosion occurs and great heat is

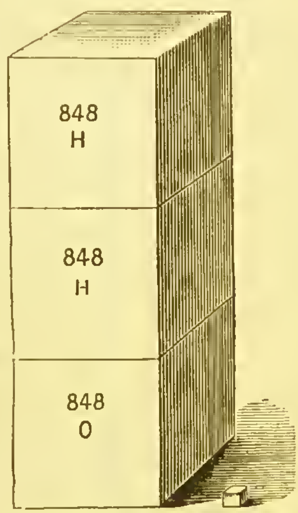

Fig. 11.

* Avagadro. The principle given is often called "The Law of Avagadro."

given out, but the same thing takes place quietly in a candle-flame because the quantity of gases combining at any one moment is very small.

This is a picture of the change.

Two molecules of **H** and one of **O** are first mixed, and because these are gases, the molecules are far apart,

(H-H) **(O=O)** **(H-H)**

The same are then united chemically into two molecules of water,

(H-O-H)(H-O-H)

Here you see we have 4 **Hs** and 2 **Os** in each case, and that if we had had more **Hs** than four, those in excess must have been left uncombined, unless we had added more **Os** to join them.

These very changes, you will remember are occurring every moment of life in our own bodies, but slowly and quietly as they do in the candle-flame. These changes are the source of the heat and power our food supplies, but which are hindered and delayed by intoxicating drinks.

A candle continues to burn by constantly getting new oxygen to supply it, but if we cut off the supply, the candle quickly goes out. Take a very short piece of candle and a card, or better a small piece of glass (see fig. 12), and fix the candle down by warming its end. If it does not stick, it will make little difference to our experiment. Now light it and

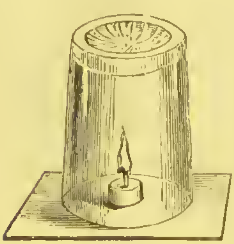

Fig. 12.

cover it with the tumbler. It almost at once becomes dim and in about four seconds goes out, but then it has burnt long enough to moisten the inside of the glass by the water it has formed, and beside this, its carbon has produced carbonic acid gas. The tumbler at the beginning of our experiment contained about twenty cubic inches of air, of which one-fifth, or four inches, was oxygen; and we might think all the oxygen had been used up, but really, when one-eighth of the oxygen is combined, the candle can no longer burn, and *we* are much like the candle in this, for, when only a small part of the oxygen of the air is gone, we are apt to die for need of it; so see how very important ventilation is. Now turn the tumbler over, keeping the card or glass quite close to prevent the air within getting changed; next slide the cover on one side (as in fig. 13), and put in a lighted wax match (*t*) or a little piece of burning paper. Of course either is extinguished, for in the air of the tumbler our candle could no longer burn; and if a little mouse could be dropped in without admitting fresh oxygen, it would soon die.

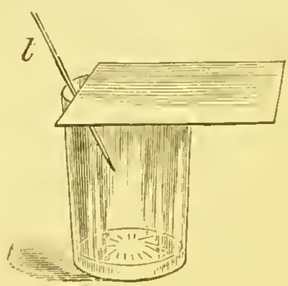

FIG. 13.

We have seen the formed water in the shape of moisture (fig. 7), but we have yet to prove the presence of the carbonic acid gas, and this will next occupy our attention.

Water is the most abundant substance within our knowledge, covering three-quarters of the surface of our earth. Without it nothing can live, for, as we have already said, it is three-fourths of plants and animals. It enters largely into every kind of food, and nothing can really feed until it has been dissolved in it. It is not only the principal part of milk and all other wholesome drinks, but of beers and wines, and, in fact, every alcoholic beverage. The most confirmed water-hater is, after all, dependent upon it, and our breweries only furnish water which we are going to show they have spoiled by injurious additions.

CHAPTER IV.

The Chemistry of Carbonic Acid Gas.

OUR task now is to find the carbonic acid gas in the tumbler in which our candle was burnt (see fig. 13), and for this lime-water is required. Lime-water is simply water that has lime dissolved in it, the solution being beautifully bright and clear. The lime in melting or dissolving in the water disappears from our sight just as sugar, or soda, or salt would do.

Lime-water is not only much wanted for chemical experiments, but is sometimes given in medicine, and we ought therefore to know something about it. To make it we need lime in the form in which it is used in mortar making. To produce this lime, chalk is dug out, and heated red hot in a kiln (the process is improperly called "lime burning)." Chalk is composed of lime and carbonic acid gas united together. The latter is driven off by the heat, and, of course, lime is left. For our lime-water we can get a little lime from a builder, or we can manufacture for ourselves by simply putting a piece of common chalk (not black board chalk), the size of a

walnut into the fire, and keeping it red hot for an hour or more. When this lump, now of lime, is cold add a little water to it. It will swell up, crack, and become a powder, so that we can easily get it through the neck of a bottle, which should hold a pint at least. When the lime is duly inside, fill nearly with water, cork carefully, shake well, and put the mixture by to settle.

Our lime-water is now complete and ready for use, for a small quantity of lime ($\frac{1}{700}$ of the weight of water), about $\frac{1}{4}$ oz. to a gallon dissolves so readily that it did so while we were shaking. The rest of the lime lies at the bottom; and, so that we may have our lime-water quite free of the sediment, it is best, for each set of experiments, to pour off without disturbance into a second smaller bottle, not forgetting careful corking. Fill up the large stock bottle with water, shaking it each time it is drawn upon, and a supply will always be ready till the lime is exhausted.

Lime-water can show the presence of carbonic acid; or, as the chemist says, is a test for it, because the lime rapidly combines with it, and then, as we know from the previous explanation, becomes once more chalk, or carbonate of lime, which is its chemical name.

When the bright lime-water comes into contact with carbonic acid gas, it becomes cloudy. The chalk formed cannot dissolve, and so separates from the water, making it strongly milky in appearance, and then very slowly sinks to the

bottom. The chemist would say that the carbonate of lime was precipitated or thrown down.

The $\frac{1}{4}$ oz. of lime that one gallon of water will dissolve, would, when made into carbonate of lime or chalk, require 168 gallons to dissolve it. Nearly all the chalk formed therefore must settle.

Having our lime-water prepared beforehand, we go on with our experiment with the tumbler (fig. 13), and pour in a table-spoonful. The lime-water begins to combine with the carbonic acid gas, but it can only do so on its upper surface, where the gas is in contact with it, so we gently shake the tumbler, and quickly the lime-water becomes milky, the proof of the presence of carbonic acid gas, as before explained. Indeed, now it is no longer lime-water, but chalk and water, or more correctly, carbonate of lime and water, the milkiness being caused by the carbonate of lime floating about as a very fine powder.

Let us now study the composition of carbonic acid gas. We remember that when hydrogen burns, one oxygen and two hydrogen atoms combine forming the water molecule thus (**H-O-H**), page 31, but the case is different when carbon burns, then one carbon atom joins with two oxygen atoms, which we may represent in this way **O=C=O**. The chemist, however, saves trouble by writing $\mathbf{CO_2}$* which means carbonic acid gas, or, as it is now generally called, carbon dioxide. Our fancy might tell us that the two oxygen atoms are like wings to the solid carbon

* Should be read C, O, two.

so that they fly away with it, and make it part of a gas. CO_2 has very singular properties, which we cannot well examine until we have it by itself, so that we must now make some in a pure form, for the tumbler in which the candle has burnt (fig. 13), contains a great deal of nitrogen, some water in vapour, some oxygen, and not more than two per cent. ($\frac{1}{50}$) carbonic acid gas, which, however, was quite enough to show itself with our lime-water test.

There are several ways in which we could get carbonic acid gas from chalk by the action of acids, but, perhaps, the very easiest is to use carbonate of soda, in a little experiment in which almost all boys and girls delight. If we mix tartaric acid, carbonate of soda, and pounded sugar together, we get a mixture called in the sweetmeat-shop sherbet, and young people all know that, when water is added to it, there is a most charming fizzing, which tingles the nose if they take a drink, as they surely would if they had a chance. Let us see the meaning of this fizzing. We should rightly conclude that, as carbonate of lime is lime and carbonic acid gas, therefore carbonate of soda is soda and carbonic acid gas. The tartaric acid may be mixed in powder with the carbonate of soda, and do nothing while it is dry, because the molecules (you know the word now), cannot get close enough together for any changes, but when the water comes the powders melt, and then the tartaric acid joins with the soda, and the carbonic acid

gas is turned out by itself, like the deserted carbon of the second lesson, it then bubbles up through the liquid and makes the fizzing called effervescence; and all that I am going to describe to you about carbonic acid gas or $\mathbf{CO_2}$ could be managed with sherbet, although the following plan would succeed better.

Have ready three tumblers, a light, and some tapers. Now take a tumbler (A, fig. 14), and put into it a heaped tea-spoonful of carbonate of soda, and pour upon it a little diluted sulphuric* acid, when we get even more fizzing than sherbet gives. Now, putting in a lighted taper, it is instantly extinguished, and no smouldering occurs. Lifting the tumbler as at B, we can pour

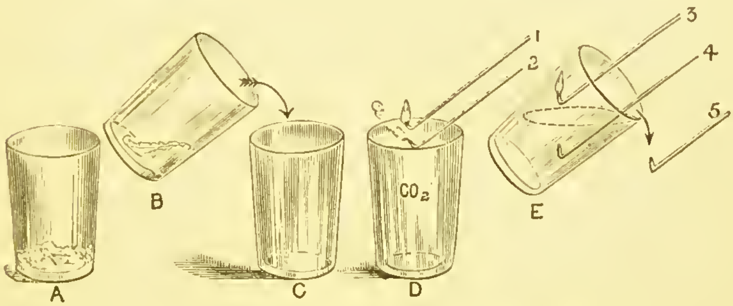

FIG. 14.—EXPERIMENTS WITH CARBONIC ACID GAS.

* Strong sulphuric acid is very cheap, but very destructive. It is much better to keep some mixed with about six times its bulk of water, when it can be placed in a corked† bottle. If sulphuric acid is thought objectionable, tartaric acid and water may be used. Vinegar, which is sometimes suggested, is not suitable.

† If corks be soaked in vaseline, they may be used for even strong acids, and are most serviceable.

the heavy CO_2 (for it is $1\frac{1}{2}$ times the weight of the air), into the tumbler, C, and there test its presence by extinguishing the taper as before. To do this, there should not be a strong draught in the room. If we fill the tumbler completely we shall find, though we can see nothing, that the moment the taper passes from D 1, where it will burn as usual, to 2, just below the rim, it will go out, almost as though the tumbler were full of water, although at the very edge of the gas, where it is mixing with the air, the taper will smoulder, as shown in the illustration. Now, lifting D, and giving it a sharp movement, as though we were throwing water out of it, we shall find all the CO_2 gone, for the taper will now burn, even at the bottom of the glass. Recharging A by using more acid, and refilling a tumbler from it, we can pour it over a lighted taper, as at 5 E and put it out, while the taper will burn at 3 but not at 4, the carbonic acid gas becoming horizontal at top, as shown by the dotted line E.

We now try our lime-water test by adding it to a tumbler full of carbonic acid gas when we get very strong cloudiness from the formation of carbonate of lime, showing that the CO_2 made from carbonate of soda is exactly the same as that made by burning carbon. An animal plunged into CO_2 dies very quickly, and comparatively painlessly. Many years ago I put a diseased cat into a large jar filled with CO_2 to save it from a more painful

death by poison, and no sooner had the cat's head passed into the heavy gas that it sunk down, and the animal never moved again. At Battersea, the Society for the Prevention of Cruelty to Animals receives lost dogs, and those that are homeless and diseased, or injured, are put into a cage, which is lowered into carbonic acid gas. All is quickly over, with scarcely a struggle.

The brewer produces large quantities of this gas CO_2 and he also finds that it is very heavy, tending to remain in his vats even after they have apparently been emptied. If the brewer's man descends into one of these before it has been properly cleared he is in danger of suffering the fate of the diseased cat or the lost dogs, as he usually falls down at once in a condition of insensibility and dies quickly, unless lifted out of the gaseous poison. Many sad instances have occurred in breweries, when other men going to the rescue of a companion have themselves fallen victims, until even four or five have lost their lives. In such cases a wet cloth wrapped round the mouth and nose is useful, as the water absorbs some of the CO_2 from the air that passes through it.

The practice is often followed of lowering a candle into a vat or well, or any place where there is danger of CO_2 collecting before venturing to descend. If the candle continues to burn, it is considered that the air is sufficiently free from CO_2 to permit of its being breathed without risk.

Although CO_2 will collect in quantity where it is being rapidly produced, it is continually slowly dispersing, or to speak more properly diffusing, because the molecules of gases are never still, but very rapidly darting about. Gases in consequence slowly, but so perfectly, mix themselves together that there is no greater proportion of CO_2 in the air near the ground in a valley than in that on the mountain top.

These are the properties of CO_2. It is colourless and without smell, and so heavy that it can be poured from one vessel to another. Its taste is acid, and we notice it when we drink sherbet, and though a little is not harmful in the mouth, it is fatal if breathed in any quantity. It extinguishes flame instantly, and makes lime-water cloudy, because it forms insoluble carbonate of lime.

Since the oxygen gas which combines with bodies in burning has weight, it is quite evident that the weight of the products of combustion or burning must be greater than that of the bodies consumed; the water and carbonic acid gas must weigh more than the tallow or gas from which, by the addition of Oxygen, they have been produced, and it is interesting that 1 lb. of tallow forms on burning 1 lb. 2 oz. water, and $2\frac{3}{4}$ lbs. of carbonic acid gas, while 1 lb. of paraffin oil produces 2 lbs. 4 oz. water, and 2 lbs. 6 oz. of carbonic acid gas. So much oxygen is combined, that a pound of candles completely spoils 1500 cubic feet of air, and 1 lb. paraffin oil

1800 cubic feet. How can it be then that the air is still pure, when it has had bad gases constantly poured into it for ages? Very wonderful and instructive is the answer to this question, and presently we shall try to make it.

For more advanced Students.

Why is CO_2 such a remarkably heavy gas, stopping some time in the tumbler, pouring out almost like water, and remaining at the bottom of brewers' vats? The question is a little difficult to understand, but it is worth an effort.

Hydrogen	atoms	weigh	1,	therefore	the molecule	weighs 2.
Nitrogen	,,	,,	14,	,,	,,	,, 28.
Oxygen	,,	,,	16,	,,	,,	,, 32.

The air contains nearly four times as much Nitrogen as Oxygen. It has therefore 4 molecules weighing 28, to 1 weighing 32. The average weight of the air molecule is, in consequence, 29, or, as we have said $14\frac{1}{2}$ times as heavy as Hydrogen. The carbon atom weighs 12. The carbonic acid gas molecule is $O=C=O$; its weight is therefore $16 + 12 + 16 = 44$. But equal volumes of all gases under like conditions have the same number of molecules, therefore weights of equal volumes of CO_2 and air are as $44 : 29$, or as $1\frac{1}{2} : 1$ nearly.

CHAPTER V.

How the Air is kept Pure.

It is likely that the last chapter caused the reader to wonder how the air could continue to be fit to breathe, as burning gas, and candle, and paraffin were always pouring deadly carbonic acid gas into it. But these sources of impurity are small in comparison with some others. There are the great volcanoes, with mouths some of them a mile or more across, sending out poisonous vapours, to which additions are for ever being made by every kind of decay the world over. Man, too, is always at work, and is a great spoiler of the air. On the land he has

Fig. 15.—Volcano.

his thousands of great chimneys, and millions of smaller ones smoking almost continuously; and on the ocean, his huge steamers crossing and recrossing day and night, belching black streams made from the burning of thousands of tons of coal; and this is not nearly all, for we shall have to learn that animals can only live as they spoil the air by their breath, and that when they die they fill it with terribly injurious gases. How can it be then that the air is as pure, as bright, as clean to-day, as it was a hundred ages ago? A very beautiful arrangement exists to keep it in perfect order, and this arrangement supplies our subject.

Give to a chemist any number of plants or parts of plants, as unlike as possible—roots, leaves, wood, bark, flowers, seeds—and ask him to analyse* them, and the result will be in every case similar. Oxygen, hydrogen, carbon, and nitrogen, with generally a smaller quantity of other matters, the principal being phosphorus, sulphur, and potash. Carbon is, however, always present, and can be easily found by heating a vegetable substance strongly, while the air is kept away. Thus charcoal is made by burning a quantity of wood together, covered with grass and lumps of earth, so that only a small amount of air can reach it. The hydrogen gets its share of oxygen (see page 22), and goes off as water in vapour, but most of the carbon has to go without, and hence remains behind as charcoal.

* Find of what they are made up.

Now let us consider how plants procure the carbon which they contain in such abundance. Their leaves, and their stems also if young and green, are covered with tiny mouths, so small that only the microscope can show them. Through these the air passes, and carries with it the carbonic acid gas, formed as we have described, and this in a most wonderful manner, is divided into the carbon and oxygen from which it was made. The carbon remains in the plant, and the oxygen is returned fresh for animals to breathe and fires to consume.

If we take a leaf, say from the garden lily, and just cut through the skin or epidermis of the under side, we can peel or tear off a sufficiently large portion for our purpose. Looking at this in the microscope, we find curiously-formed cells, *s*, *s*, A (fig. 16), called stomata, from the Greek *stoma*, a mouth. We get a better notion of these cells from B, which is magnified 250 diameters, or as much as would make a fly appear ten feet long. Here we see two cells, resembling a pair of negro lips, with an opening between them. The lips can also open and shut, making the opening large or closing it as circumstances require. If the earth in which

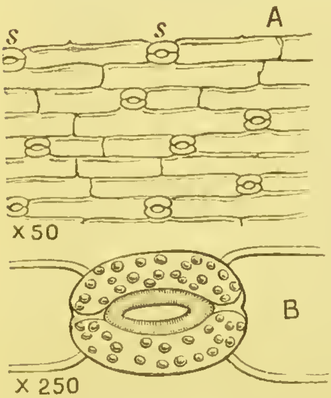

Fig. 16.
Stomata, breathing openings of Lily Leaf.

the plant is growing becomes dry, the mouths are closed so as to prevent evaporation from the leaves, but usually they are open as in the figure.

The number of these little mouths is astonishing. The barley plant, the seed of which is made into brewers' malt, is closely dotted with these little mouths on its stalk and leaves, the latter having about 30,000 and 28,000 on each square inch of their under and upper sides. The lily carries yet more, having about 60,000 on every square inch of surface. The apple tree has about 100,000 on every leaf, and the lime tree about ten times as many. A large oak, as it puts on its green dress in the spring, forms about a million millions of them! What a wondrous world is this!

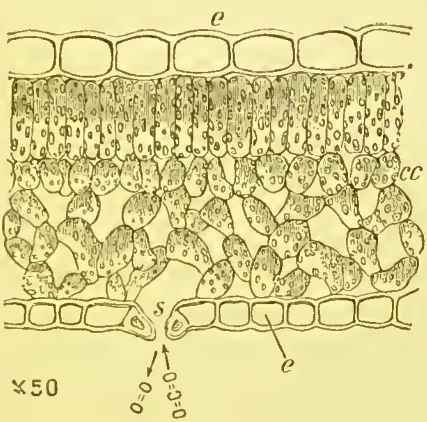

FIG. 17.—SECTION OF LEAF.
e. Epidermis ; *cc.* Coloured Cells ;
s. Stoma or Breathing Opening.

Cutting a green leaf through its thickness, and looking with a microscope at the surface of the cutting, as in fig. 17, we find that the soft parts within are protected by an upper and lower skin or epidermis, *e*, *e*, formed of hard and colourless cells, and these are sprinkled over with the stomata, of which one (*s*) is seen in section. The front view we have already noticed at *s* A,

fig. 16. Between these skins lie green, soft, and watery cells, *cc*, containing a large number of little round bodies or granules. Between these cells, again, are numerous cavities, into which the air that passes through the stomata, enters and really circulates through the leaf, if it does not do so through the plant. Into these cells the carbonic acid gas as a part of the air is taken, and divided as before explained, and as here represented by the arrows, oxygen passing out into the air. But the most beautiful part of the story remains to be told.

It is only in light, when the sun* is present, that the leaf *can* accomplish the work of dividing carbonic acid gas. The atoms of carbon and oxygen hold together with great power, and a greater power is needed to divide them, and that comes from the sun. On a burning hot day, in the thick of the forest it is delightfully cool. The leaves give shade, after the fashion of a great umbrella, but they do much more—they absorb the sun's power, and it does work in them and so vanishes. The heat disappears—it goes—but in the separated carbon and oxygen there is the power to produce it again when *they* are joined in the process of burning.

An oak, or any other timber tree forms the material for its wood in its leaves, and as it does

* Experiment has shown that plants can grow in some forms of intense artificial light, such as the electric light, but a little thought will enable the more advanced student to see that these artificial lights are after all sunlight indirectly supplied.

so, the heat of the sun seems to be lost; but after many years the tree is cut down, and the log on a winter's night sparkles and crackles in the fire. Think of it. The heat and the light it is giving out, as it goes again into the form of carbonic acid gas and water, are the heat and light given to it, by the sun, while it was growing, and locked up in it so long as it remained in the form of wood.

You remember that coal is produced from trees and great ferns that grew ages upon ages ago, they formed their material as the sun helped them with its light and heat and so when we burn the coal, we are getting again the heat and light (the energy or power we might say) which came from the sun many thousands of years before we were born. Stephenson, who gave us our first railways was asked once, what drove his train, and he replied, "The Sun." His meaning is now plain. The coal burning formed the heat which made the steam, and the steam moved the engine, but it was the heat that did it all, and that heat was a gift from the great and glorious sun, or rather from Him who made the sun, and whom David called "a Sun and shield."

Here we have the first half of a great lesson which it is most important for us to remember, as upon it stands a great deal that is to be said hereafter in reference to intoxicating drinks. It is that the heat of the fire, and indeed the heat of all burning bodies, comes from the Sun, and beyond this, that whenever oxygen unites with a

substance, heat is given out whether the combination takes place rapidly, as in burning, or slowly, as in ordinary decay,* for the latter process almost exactly resembles that of combustion. Suppose an oak post, weighing 100 lbs., to be stuck in the ground. It may stand two or three centuries, but then it will, in parts at least, be considerably decayed, while its weight will be greatly reduced. It has been from the beginning very slowly uniting with oxygen, and forming its hydrogen into water, and its carbon into carbonic acid gas. These products have escaped and so reduced its weight. During their formation, heat has been produced, and exactly too in the same amount as though the hydrogen and carbon had been burnt in a furnace. The heat has, however, been produced with such extreme slowness that it has not been apparent.

Presently we shall have to learn that our foods are the source of all the heat we are capable of producing, and that that heat comes from the sun. The same is also true of our bodily power. It is only as we burn wood and burn coal that we get heat from them, so do we only get heat and power from our foods, as they are burnt slowly—*i.e.*, united with oxygen in our bodies. People through not understanding this, have said many foolish things about intoxicating drinks. They tell us they delay the burning up of material within us, and so are a saving. They *do* delay the burning up of material, but because they do

* See experiments at end of Chapter XVII.

so they reduce our power and prevent us from conquering and accomplishing so much as we could without them.

Let us review the wonderful circle in which carbon travels. It unites with oxygen and in so doing gives heat to the furnace, light to the flame, and power and warmth to men and animals, but going off into the air it poisons it, and new supplies of fresh oxygen are constantly required. The carbonic acid gas is quickly so spread abroad that we find it to be in open spaces less than $\frac{1}{2000}$th of the air, but even so much is enough to provide to plants, perhaps their most important food. Thus the carbonic acid gas is not allowed to increase in quantity, for it with the air passes into the numberless mouths, of grass and shrubs, and trees, whence it does not return. They by the aid of the sun secure the carbon for forming their starch, their sugar, their oil, their wood, and in so doing purify the air by setting the oxygen again free. At the same time that oxygen is again provided, the foods and fuel of men are in the substance of plants once more formed for providing heat and power, and thus reproducing carbonic acid gas and so the circle of mutual provision between plants and animals is completed.

CHAPTER VI.

Plants as Food-Makers.

In our last chapter we traced to the vegetable world, coal, our most common fuel, but a little thought will show us that everything that will burn in its natural state, giving us heat, has been originally vegetable. Of wood and coal; and charcoal and coal gas, made from them, no more need be said; but it ought to be explained that paraffin oil, rock oil or mineral oil, has been produced from coal by a sort of distillation carried on by the natural heat of the earth far below the surface, and that, therefore, all these oils, whatever their name, came from plants just as much as linseed oil and olive oil have done. Resins and turpentines, pitch and tar, are made from wood, and so these are vegetable in their origin, and so is also a description of tar called coal tar, which is produced in large quantity during gas-making; spirits of wine, again, used often in lamps to give heat, and of which so much must be said by-and-by, is made from sugar, a plant product.

But what of the tallow and wax of candles?

Are these vegetable? The tallow comes from the vegetable food of the sheep, and the wax from the sweet juices of flowers gathered up by the bee, and then strangely altered in her little body into the material of which her comb is built, and this melted down gives us wax, which is afterwards bleached for candles. And so we might trace the vegetable origin of every heat and light-giving substance that we examine, and for a reason that should now be understood by us. It is because plants grow by using up the sun's heat and power, so that when they, or the substances formed from them, are destroyed by burning, their hydrogen becomes water, and their carbon, carbonic acid gas, and the heat and power of the sun is given up again; and so the sun is the source of all the heat and all the light of every kind that we possess, with the one exception of that from the stars, and they are distant suns giving heat and light to other worlds.

We have now another step to take. Not only do we owe all fuel, but all food to plants.* There are many persons who entirely avoid the flesh of animals, and they are called vegetarians; but in a certain sense all are vegetarians, not even excluding the lion, the eagle, and the shark.

You will see at once that beef and mutton are but second-hand grass, and that fowls are *chiefly*

* Water is not here included, as it is rather a food solvent than a food proper. Salt as added to that derived from plants is a non-essential, although commonly desirable.

altered corn. But the rest of their food, if not actually vegetable, *is vegetable in origin*, including the insects and the worms of which they are so fond, and which get so completely changed by digestion, that at last their material may be relished at a rich man's feast as very good chicken. The worms are vegetarians direct, living upon decaying vegetable matter found in the soil, and although many of the insects consumed by the fowls may have preyed on other insects smaller than themselves, yet, these have been vegetable feeders, or have depended on others, perhaps, still more minute that have been. We always at last get down to plants, which are the providers of nourishment and support for every individual of the animal world, whether large or small. The necessity for this is clear, plants pick up power from the sun, animals cannot do this, and so they are forced to come to plants for all the energies they possess. The main distinction between vegetarians and meat eaters lies in this —that whilst the former take their food in plant form, the latter take it after a change or two, in the bodies of animals when we call it animal food.

In our future study of intoxicating drinks, we shall have to ask what their value is, and what their claim to be called foods, and, therefore, it is most important for us now to notice how plants prepare our nourishment, and upon what its virtues depend in order that we may see how intoxicants fail altogether, although of

vegetable origin, in performing what food must be capable of doing for us.

The food, we obtain from plants, has all been prepared for plant use. You have often eaten parsnip. In the spring, the seed is sown, and in the autumn the parsnip is dug up large and full of food, but the parsnip has not produced any seeds. To obtain these, the root must be left in the ground, and the second year, the parsnip pushes up little blossoms and then seeds follow. To feed, and form these the nourishment is used which was gathered the year before into the root, which is in consequence after seeding left woody and useless. We see now that we feed on the store the plant had saved up for its own purposes.

The potato teaches us a similar lesson. It is a collection of nourishment to feed the young plants which may grow from what we call the eyes (*e*, *e*, fig. 18). These being really small buds, which sprout (*s*) and at last make new plants. Farmers actually obtain these by putting into the ground pieces of potato having eyes upon them.

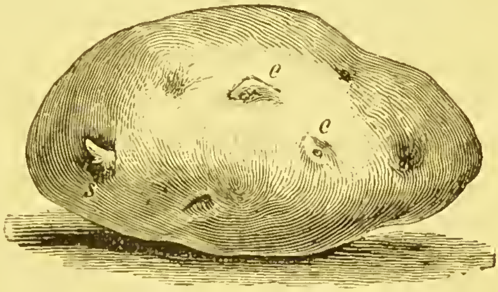

Fig. 18.—Potato with Eyes.
e, *e*. Eyes ; *s*. One sprouting.

All know that the potato contains much starch

This can be found by grating or scraping a small piece in water, when a white sediment consisting almost entirely of starch will remain.

Every part of every plant is full of marvels, and examining a scrap of potato by the microscope, we see it made up of minute cells or bags—four or five of which are drawn at fig. 19. Every cubic inch of the body of the potato contains about eight millions of these. The thin sides (*s*) of these little bags are flattened as the cells press together, just as soap bubbles have flat sides where they touch one another. Within the cells are still smaller bladders (*g*) full of starch, and much the shape of eggs. By careful measurement, I find their average diameter is $\frac{1}{800}$th of an inch, and a moderate-sized potato contains 500,000,000 of them.

FIG. 19.
CELLS OF POTATO.
g. Granules of Starch.
s. Side of Cell.

These are known as starch grains or granules, and, by sinking to the bottom, they formed the white sediment left after scraping, as just now explained. When the potato is cooked, the thin (cellulose) cover of the granule breaks, and the starch escapes.

Almost everybody, if asked, would say that a potato grows underground, but there is a sense in which this is not true. Its substance is not there produced; it is manufactured in the leaves

of the plant in the sunlight. All plants, in fact, grow in the leaves; they are the workshops in which the matters used in building up the plant are put together.

It might appear fanciful but it is really true that fruits are similarly produced in the leaves. Every apple, every pear, every plum has passed through its own stalk in the form of sap, of which it has been built up. Its material has thus been once liquid and so capable of movement in the vessels of the living plant, but having been carried to its required destination such changes have been brought about as were necessary to convert the liquid into the solid matters which the fruits with their enclosed seeds contain.

Remember carbonic acid gas enters the leaves by the stomata (*s*, figs. 16 and 17), and carbon is retained. In a way, not yet quite fully known, the elements of water are combined with this carbon, and from these starch, sugar, gum, wood, and a great many other matters are formed. The plant, so far as we are able to see, begins by making starch, and let us try to trace the process. One molecule of water consists of **H-O-H** (see page 31), commonly written $\mathbf{H_2O}$. Therefore, five molecules of water would contain $\mathbf{H_{10}O_5}$. The plant unites to these six atoms of carbon, and the result is $\mathbf{C_6H_{10}O_5}$=starch,* minute particles of

* Chemists now generally write $(C_6H_{10}O_5)n$, as it appears certain there are over 400 atoms in this complex molecule, but, our formula giving the correct proportions, is enough for the purposes of this work.

which can be discovered by the microscope in the process of making in the green parts of the leaf cells.

Starch will not dissolve in water unless it be considerably heated, and so cannot, as starch, be carried about in the sap or fluid of the plant. It is, therefore, very soon changed into a body which dissolves most freely—I mean sugar. This is done by uniting another molecule of water with the starch, a process which man can and does imitate in the making of intoxicating drinks (see Converter, Chapter XI.). It is, of course, *not* a mixture, as that would form only starch and water, but a joining up of atoms, which are even put together in a definite arrangement, just as the coloured pieces in an inlaid floor, or a patchwork quilt, have to go together in a regular order to form a pattern.

Here we have the alteration put down as the chemist writes it, and it should be remembered carefully as it will be referred to hereafter :—

$$\begin{array}{rl} \textbf{Starch} = & C_6H_{10}O_5 \\ \textbf{Water} = & H_2O \\ \hline \textbf{Grape Sugar} = & C_6H_{12}O_6 \end{array}$$

The leaf is busy with other work besides starch and sugar-making. Materials brought from the roots are worked up with the carbon into many kinds of plant food, generally containing nitrogen, and these, with the sugar, are distributed to those parts that are in need of them, such as the growing

potatoes; and now another of those chemical puzzles which plants are constantly performing occurs, for little by little the sugar, in a round-about way, is once more brought into the form of starch, and stored in those millions of little packets, shown at fig. 19.

Life means change, and even now, after all this beautiful packing up, the starch is not long so to remain, for when the next spring comes round, and the parent potato plant is dead, the buds in the eyes commence to shoot. Then the starch once more begins to become sugar, and escapes from the containing cells to form the sap of the little plant; feeding it during its weakling days until it is strong enough to get its own food by its newly formed leaves and root. This even happens with potatoes out of the ground, for in the spring they become sweet from this very change. You say, why all these alterations? If it is to be sugar at last, why should it be stored as starch? Is there any need for the plant to be at so much trouble? Yes, sugar would be a most unsafe store. Fancy a potato full of it lying in the ground waiting for growing time. Here is a little beetle, with a good appetite, and strong jaws, scraping his way through the earth, evidently making for our potato. No sooner does he reach it than he cuts a hole, and makes an excellent dinner; and the winter rains will now by that hole enter, and wash out all the sugar, and so ruin the potato. No, the store must be

insoluble starch; then the beetle may feed as before, but very little harm will be done, for the starch remains and does its work at last.

We must now give some attention to seeds, as these form so large a part of our food:—wheat for bread, barley for malt, oats for porridge, rice, peas, beans, lentils, coffee, cocoa, and nut kernels all being seeds. Let us take wheat as a

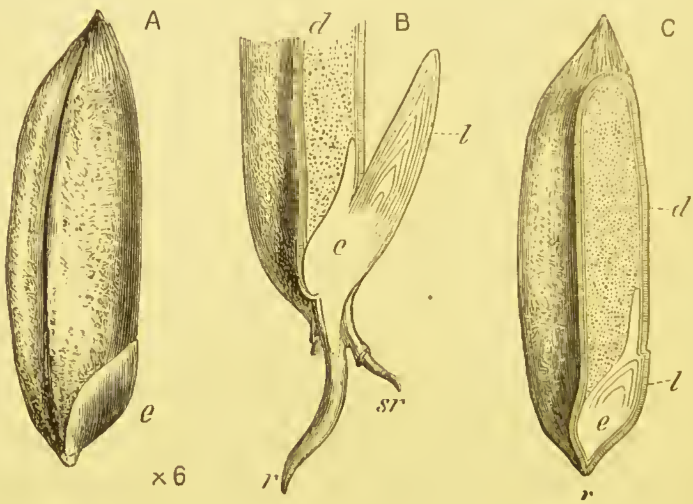

FIG. 20.

A. WHEAT GRAIN. C. SAME IN SECTION.
B. SAME AFTER THREE WEEKS' GERMINATION.
d. Food Store; *e.* Embryo for Young Plant;
l. Leaves; *r.* Root; *sr.* Secondary Root.

type of the others, because of its great value and importance. Remembering that what is said of it is exactly true of barley also.

By slightly magnifying, a wheat grain A, fig. 20, a prominent scale (*e*) is found at its lower extremity. This is the beginning of a new

plant; if we cut the grain down the centre, as at C, we can examine it in section. The whole of the upper part (*d*) is a store of food, beneath which lies the little plant (*e*), called the embryo. Not much can be seen of its parts, but when the seed is put into the ground the point (*r*) elongates, forming the first root, while the leaves (*l*), now lying one within the other, become more definite, C, and by degrees grow up; next the stalk forms, and at last the ear is produced above. The mass of food (*d*) consists largely of starch grains somewhat smaller than those of the potato, while in the cells in which they are packed are also found much smaller granules,* which contain nitrogen, and contain the albumen of which much will be said under "Ale and Beer."

During the early growth of the wheat plant, as in the budding potato, this nourishment becomes soluble, the starch as before changing to sugar, and then some of it unites with oxygen, yielding heat and energy to the plant, enabling it to do the work involved in growing, and, just like a burning candle, being changed into carbonic acid gas, or carbon dioxide, and water, which we can represent thus:—

Sugar + 12 Oxygen = 6 Carbon Dioxide + 6 Water.

$$C_6H_{12}O_6 + 12\ O \quad = \quad 6\ (CO_2) + 6\ (H_2O)$$

I cannot allow this chapter to close without a

* Aleurone granules.

little reflection. Suppose we could so magnify these atoms about which we have been talking, that we could see each one and trace its movements. With what wonder should we watch the carbon and oxygen breaking apart within the leaf, and the oxygen in pairs marching out again, while the carbon, hydrogen, and oxygen join up into a beautiful and regular, though very complicated pattern, forming starch molecules. Presently each one takes for a companion a molecule of water, and they then together rearrange themselves into a new but not less complicated order, forming sugar molecules; then these in multitudes swim away, some quickly, some slowly, to their destination, with as much seeming purpose as soldiers under orders. They are going in every direction, some are taking their proper part in forming straw, some chaff, while some are seed builders, and these, having at length arrived in the growing ear of corn, once more change their pattern, as though a marching battalion formed into square; and now they arrange themselves, taking up position side by side, and packing themselves in millions of little bags to form the starch granules. Intermixed with these, more complicated movements and changes are occurring. Oxygen, hydrogen, nitrogen, carbon, phosphorus, and sulphur, are all busy, and doing marvels. Strange, indeed, and very varied, are the patterns that *they* are making. All are working together with a wondrous harmony getting ready

for the many needs of the little plant which shall be produced the coming year. If we *could* see these things, and they are but a fraction of what is really occurring, our hearts would beat the faster, and in wonder we should exclaim, "They are alive! each one must know what it ought to do!" They are alive, but *they* cannot know. The root cannot think for the leaf, nor the leaf for the ear, nor either for the grain, which is to live and fruit when they are dead. It brings us back to Him who "maketh the grass to grow upon the mountains," who "clothes the grass of the fields," and "who openeth His hand and satisfieth the desire of every living thing."

SECTION II.

INTOXICATING DRINKS.

CHAPTER VII.

Fermentation.

IT is unfortunately impossible for even young people not to have had evidence forced upon them of the bad results of intoxicating drinks, and later on we shall particularly study their action on our bodies; but first we must understand how they are produced, and what they contain as distinct from ordinary articles of diet.

The word "intoxicating" has an origin which is interesting. It comes from an old Greek word (toxicon) meaning the poison into which arrows had been dipped so that their wound might prove fatal. These drinks then, by their very name, are declared to be poisonous, and since they are made, with but very few exceptions, from good foods—wine from the luscious grape, ales and beers chiefly from barley, while spirits have in most cases a similar origin—we naturally ask how then can they be injurious? Their bad

qualities are almost entirely due to the presence of a liquid once called spirits of wine, but now generally known as alcohol.

The old chemists, who had to give names to things they discovered, were fond of the word "spirit." By heating the horns of the hart or deer, and catching the vapour, they obtained what they called spirits of hartshorn, now ammonia; by treating turpentine in the same way they made what they called spirits of turpentine; so when they heated wine, and then condensed the vapour, the white and light liquid produced they named very naturally "spirits of wine," but the Arabian name alcohol is now most usual.

If alcohol then, the greatest mischief-worker both to the bodies and souls of men, can be obtained from wine direct, and in the same way may be separated from beer, how came it in the wine? How came it in the beer? No alcohol is found in grapes! No alcohol exists in barley! No alcohol is anywhere found in living plants. No animal body in any part contains it. Blood and brain and nerve and muscle are all free of it, save in the sad exception of man, where he, in his folly, has called poison food, and has made and swallowed that which "biteth like a serpent and stingeth like an adder."

We said alcohol is nowhere found in *living* plants; the leaves, the seeds, the roots of all are absolutely free of this substance. So of the fruits, the luscious plum, the delicate peach, the juicy grape contain none of it as they grow

ripening and colouring until they are full of delicious and wholesome food; *but*, when their skins break and they pass into the stage of decay, alcohol may be formed as rotting progresses, from which we may begin to trace its origin. *Alcohol is one of the results of death, decay, and decomposition*, without which it cannot be produced. The more carefully we trace its history the more completely shall we realise that of life it is the enemy, of death it is the child.

All animal and vegetable substances containing much water, when they cease to live, are liable to change, or, as we say, go bad, and a short study of their changes will prepare us to understand what is meant by fermentation, the process by which intoxicating or alcoholic drinks are prepared.

New milk in the winter will keep good for two or three days, but, in the summer, it quickly turns sour and curdles, because the sugar which the milk contains undergoes a change, and from it an acid, called lactic acid or milk acid, is produced. In recent years, it has been clearly proved that this alteration in milk is caused by multitudes of little living bodies, which are so exceedingly minute that they can float about in the air, and a really good microscope is required to see them.

When the milk is freshly drawn from the cow, none of these little bodies can be discovered in it, but, if it be examined by the microscope

when it is souring, it will be found to be literally full of them. Strange as it may seem, they are all swimming about in the most active manner. The way in which they get into the milk is now no mystery. Some few fall in from the air, and then these multiply at a marvellous rate. Suppose one of these (*a*, fig. 21) to fall into the milk, it pushes out at its ends two little threads which it lashes about, and by which it swims. It takes in new material by absorbing it through its sides, and so grows, rapidly getting longer. Presently it narrows in the middle as at

FIG. 21.—BACTERIUM LACTIS, WHICH CAUSES SOURING IN MILK. *a, b, c, d.* Stages of Division.

b, and its waist continuing to become more slender, we soon observe it as at *c*, but it does not snap in two as might be supposed. The two parts now draw from one another and pull out a thread by the side of which the spider's web is a thick rope, the thread breaks at *d*, and we have now two distinct bodies, which we ought to call *bacteria lactis* (for such is the name used by scientific people), swimming in the milk. These two pass through the same changes, and in a quarter of an hour or so, become four, and so on, always doubling in number every few

minutes, so that in some hours the one becomes an army, for if we continue to multiply by 2 see how the numbers enlarge, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, and if this took two hours, at the end of the next two hours there would be 1,048,576.

We now perfectly understand the reason of the number of these little mischief workers, which are not animals although they swim, but plants of a simple though extraordinary kind. But what of their size?* Oh so small we cannot imagine it! a heap containing one hundred thousand millions would only be the size of a drop of water, yet they are independently alive, can move, and grow, and increase. One can soon become a countless host. As they multiply they more and more quickly injure the milk, at last rendering it completely unfit for food. This milk destroyer is one kind of ferment of which there are very many, and the change in the milk is one kind of fermentation.

But how has it been distinctly proved that these little bodies do the work of making the milk sour. Pasteur, a Frenchman, discovered that if he took milk and carefully boiled it in a flask so that all the ferments in it should be killed, and then prevented any others entering,

* 3000 under the figure means magnified 3000 diameters, or so that a flea's body would appear larger than a railway carriage, while his legs would be thicker round than the body of a cow. When we so magnify we should not be able to see more than a very small portion of the body of a flea at one time.

the milk would never turn sour. This is how we can all manage it for ourselves. Take a glass flask (*f*, fig. 22) and place in it some milk which should now be heated over a lamp until it freely boils. The steam drives out the air the flask contains, while the heat kills all ferments either in the milk or on the flask. We have now some cotton wadding which has been kept thoroughly hot in the oven for an hour or so, care being taken that it does not scorch.

FIG. 22.—*f.* FLASK; *c.p.* COTTON PLUG.

In this also the ferments are killed. As we remove the flask from the fire or lamp we carefully insert a plug of this cotton (*c.p.*), and now as the steam condenses the air will enter, but only by passing through the wadding which acts as a sieve or strainer, and prevents any ferment from entering with it. Milk so treated remains perfectly sweet. I have kept it for three years without any further change than that it gradually thickened through the water drying out of it. In trying this interesting experiment it is desirable, as an additional precaution, to give the milk another boil up on the second day.

The housewife sometimes says, "The milk will not keep if I don't scald it." The previous explanation should show us why scalding keeps it. Suppose a thousand millions of the ferments

are busy in the milk jug; they are not enough to very quickly cause curdling, but there soon would be a sufficient number if these are allowed to remain. Scalding the milk kills them all. When the milk cools others fall in, it is true, but it takes them some hours to multiply much, and by that time the milk is used. Milk keeps better in winter than in summer, for two reasons—1st, in winter there are fewer ferments in the air; and 2nd, they do not multiply so quickly in the cold.

Let beef-tea be put on one side, and in two or three or more days, according to the season, and

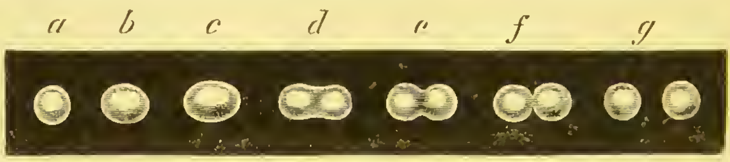

FIG. 23.—FERMENT OF SOUR BEEF-TEA, MICROCOCCUS. *a, b, c, d, e, f, g.* Stages of Division.

also according to the manner in which it is kept it will "begin to go bad." If now it be examined by the microscope it will be seen to have in it millions upon millions of little round bodies all hopping with ceaseless movement, these having been produced from a few that have fallen in from the air. Fig. 23 shows how they multiply:—The round germ or seed * (*a*) falls in from the air, in which numbers float; it grows, doing its tiny best in destroying the beef-tea, and becomes ellipsoid or egg shaped (*b*); its length still in-

* The scientific name is Micrococcus.

creases (*c*) and presently a neck (*d*) is formed; this narrows (*e*), and at last snaps as at (*g*), when two germs are ready to begin a similar set of changes. Scalding the beef-tea, like scalding the milk, will increase the time it may be kept for these germs are the cause of the putrifaction.

These facts about milk and beef-tea should enable you to see why meat, Australian beef and lobsters and Swiss milk, may be preserved in tin-cases in which they are made boiling hot, the tins being sealed down air-tight before they cool. All germs within the cases are killed and no others can gain an entrance, and in their absence there can be no fermentation and no putrifaction. When I was a lad I was taken by my father to the Royal Institution where I had, and enjoyed, roast turkey, boiled chicken, and boiled beef, all of which had been cooked twenty-six years before I was born. This was thought wonderful in those days, but now we understand it. They had been placed hot in air-tight cases.

The main object of this lesson is to show us the meaning of fermentation, as a part of the manufacture of intoxicating drinks but a very important matter about the management of our homes and the preservation of our health must be noticed before we close. The ferments and germs we have as yet studied are destructive and should be got rid of as far as possible. If we manage our home badly we increase their number, and so make our homes less wholesome than they otherwise would be.

It surprises you to hear that these germs float about in the air, I will first explain how this is. We take two boots, a right and left of the same pair, we put one on a nice dry shelf, we put the other into a damp cupboard where we have carelessly left a lot of paper and perhaps a mouldy piece of bread. We think the bread *only* is spoiling. No! it is now going to spoil our boot, for soon we find the leather covered with a downy bluish green mould like that on the bread. Taking the boot into a strong light, we give it a tap and there goes off from it a little cloud looking like smoke. (Try this when you find something mildewed.) With the microscope we see the leather covered with tiny cobweb like threads (*m*, fig. 24), which send up a multitude of little stems with branches, at whose ends are lines of round bodies like beads (*s*, *s*). These are the mildew spores or seeds, and upon the slightest touch millions of these break off in a cloud, forming the "smoke" we saw, and whenever they settle upon any thing which is damp, and which can feed them, they start mildew.

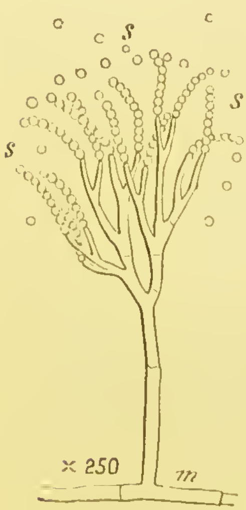

FIG. 24.—BLUE MOULD.
m. Mycelium ;
s. Spores.

Looking now at our boot on the shelf, we find it still bright and clean because dry, for although

mildew spores have without doubt settled on it they could not grow. This boot is now stronger than the other, for the mildew lives on the leather and decays it. But by keeping the boot dry or clean we have not only saved it from decay, but we have prevented the mildew germs from multiplying.

It is strange, but true, that this very mildew germ is not only a spoiler of leather and bread and glue and gum, and I know not what beside, but it is an alcohol maker, and can do the work of the brewer after a fashion, as I shall be able to show you in another chapter. It is not a friend any way, and the brewhouse has had probably a good deal to do with making it so common. Fermentation is there accomplished by yeast it is true, but this we shall see presently is very closely related to mildew.

It has now become quite plain that mildew in one place starts mildew in another, mouldy crusts fill the air with spores and make the new loaf mildew quickly, spoilt beef-tea makes the meat in the same cupboard go bad for spores from it fly about; and every kind of decay spreads spores or seeds into the air which start decay in other places. Let our food be put into a dry and very clean place, and it will keep better and be more wholesome. Dirt of every kind favours these enemies of ours terribly, as it also favours the very similar germs which cause those diseases called infectious, many of the germs of which are undoubtedly propagated by decay-

ing or putrifying substances, and may be, through want of cleanliness, kept about our homes ready to start multiplying in our bodies, and so perhaps kill us by the mischief they work. Ventilation, dryness, lime-whiting, cleanness, these are the great preservatives against disease and decay. Let us have these as well as love and kindness, and our homes even if humble may be bright and happy.

CHAPTER VIII.

Wines in General.

We are now prepared to study the manufacture of intoxicating drinks, since the means by which alcohol is obtained from sugar closely resembles the process of souring in milk, or in beef-tea—the cause in all these cases being a living germ or ferment.

We shall take wine, made from grapes, first in order, as it is the most ancient intoxicating drink, and its manufacture is more simple than that of beer or spirits ; but it is needful here to give a caution. When the word wine is used in the Bible, or by ancient writers, it does not always mean that which is intoxicating, or has been fermented. There are the very strongest reasons for supposing that the new wine which our Saviour described as breaking old bottles was grape juice only. Homer, who lived about 2700 years ago, wrote of a sweet wine, which was grape juice thickened by boiling, to which, when it was drunk, water was added ; this, of course, contained no alcohol. The Greeks often used a sweet unfermented wine they called Gleukos,

and in wine countries to this day unfermented grape juice is consumed, reminding us of Pharaoh taking the fluid just pressed from the grapes into his cup by his butler. We can procure unfermented wine in our own country now, which is simply the juice of the grape made fine and clear by long keeping and bottling, and this is agreeable, refreshing, and wholesome.

The vine, from the earliest ages, has grown wild in Asia Minor, the western parts of Asia, Southern Europe, and Northern Africa, while we have records of the cultivation of the grape in Egypt between five and six thousand years ago. Now the warmer parts of Europe have a considerable fraction of their surface covered by carefully kept vineyards, the only object of which unfortunately is to produce intoxicating wine. Thus the vineyards of France alone would cover one-fifth of the surface of England.

There are many varieties of grapes, and they can be treated somewhat differently in wine making, but you will be much surprised to hear that France alone claims to make 570 different sorts of wine, while a list of 1400 kinds has been drawn up. This is quite amusing, and the wine-tasters must be sometimes very puzzled, for we shall see presently that, although there are several distinct kinds, and that each of these can be made into a number of varieties by changes in the method of manufacture, still their actual quali-

ties are quite as nearly alike as those of the grapes from which they are made.

Grapes contain a number of substances, the most abundant solid, being grape sugar, as we shall see by the following, which is derived from the Food Collection at Bethnal Green Museum. One pound of fresh grapes, of average quality, contains :—

	grs.		ozs.	grs.
Water, . . .	5600	=	12 ,,	350
Sugar (grape sugar), .	910	=	2 ,,	35
Pectose and gum, .	217	=		217
Cellulose, . . .	140	=		140
Tartaric acid, . .	56	=		56
Albumen, . . .	49	=		49
Mineral matter, .	28	=		28

In adding this up, it must be remembered that these are avoirdupois ounces which contain $437\frac{1}{2}$ grains, so that the total, 14 ozs. 875 grs., make 16 ozs. = 1 lb. exactly.

The albumen is a valuable flesh-forming food, having the qualities of the white of an egg. The sugar is a heat-giver, as are also the gum, and pectose—the latter a kind of jelly, giving to raspberry jam its jelly-like character. The cellulose is quite useless.

The first operation in the making of wine is the breaking or crushing of the grapes, machinery being generally employed for this purpose. For some of the expensive wines, the grapes are separated from their stalks, but, most frequently. stalks, skins, and juice are all fermented together,

The broken grapes form a soupy liquid, called *must*, which, in large vineyards, is collected in immense quantities, forty or fifty tons frequently being fermented at one time in one huge vessel.

Numbers of tiny spores or seeds, something like those that get into the milk or beef-tea, but of a different kind, fall from the air on to the skins of the grapes as they hang upon the vine. There the spores cannot grow any more than a mildew germ can grow on a dry boot; but no sooner are the grapes broken than they are surrounded by food—the albumen and sugar of the grape—and now they multiply at an enormous rate. At first they are separate, but as they absorb nourishment they throw out buds rapidly, which remain fixed to the parent, so that soon they are seen in little colonies, some of which are shown at fig. 25. The two most valuable constituents of the grape disappear as the ferment increases. The albumen is really absorbed through the sides of the ferment, or as we should say of animals, is eaten by it, and so destroyed that in the end nothing will remain of at least five-sixths of it except a brownish deposit, which will be thrown away. The sugar at the same time is being divided into two new and poisonous substances—carbonic acid gas, which escapes with considerable bubbling and commotion, and alcohol, which remains behind.

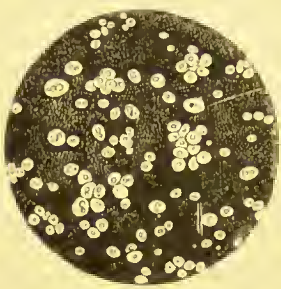
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FIG. 25.—WINE FERMENT.

There is every reason to believe that the sugar, like the albumen, is absorbed or eaten, and that the alcohol and carbonic acid gas are the waste products which the ferment bodies throw out again, just as the bad acids formed in souring beef-tea, and the lactic acid in souring milk are the refused matters or excreta of the ferments in both cases.

This process, we know, is called fermentation, and is suffieiently tumultuous to be aecompanied by a strong, hissing sound, of whieh the sherbet we once talked about would give us, when the water is added, a very faint imitation. The *must* beeomes very warm, principally because of the destruction of the albumen before referred to, in which it gives out the same powers which were required to form it in the grape when growing on the living vine (see page 50). Here observe, and endeavour to remember for future use, that whenever a food begins to *produce* heat, some of it is being lost, for it is giving out the very heat and power it could have given to our bodies had we eaten it. Indeed the ferments consume the food first, and form heat in their bodies whieh warms the must, and those who take alcohol simply get what they have left.

The escaping carbonic acid gas, in millions of bubbles, gets attached to the fragments of skin, and all the broken up parts, which are not really liquid, and earries them to the top, where they form a thick and frothy crust, protecting the fermenting juice from the action of the air, otherwise the

alcohol formed would be, even at the very outset, changed by the oxygen into acetic acid; that is, vinegar, not wine, would be produced. Carbonic acid gas, on account of its weight (page 42), collects above the crust, and here its presence now and again causes the death of the workers who are not on their guard against the danger. The fermentation may continue briskly from a couple of days to a week, or even longer. When it slackens, the wine is drawn off into great vats, where more of the material of the grape is lost in the separation of what is called lees;* some time later, usually in the winter, it is transferred to casks and carefully bunged in, or the oxygen of the air would certainly make vinegar of it.

In this wine, fermentation has practically ceased. To end it altogether brandy is often added, as explained more fully in next chapter. It may now be transferred to bottles, and kept for years with but slight alterations; ethers are, however, formed, which give an odour much liked by wine drinkers, who call it bouquet. Such wine when poured from the bottle shows no sign of frothing, because no carbonic acid gas is formed after corking. It is on this account said to be a *still wine*, as distinguished from *sparkling* or effervescing wines, which receive no brandy, and have their fermentation somewhat revived at the

* This consists principally of the acid tartrate of potash, or cream of tartar, tartrate of lime, and colouring matter. These fix themselves largely on the sides of the vat, while at the bottom the brown matter, the remains of the albumen, is found.

time of bottling by the addition of a little sugar. The carbonic acid gas formed cannot escape until the drawing of the cork, when it forms multitudes of rising bubbles. Herein lies the mystery of the fizzing of champagne and wines of this character.

We have already noticed that the grape juice ferments of itself, just as beef-tea goes bad, or as milk sours, because the germs causing these changes are everywhere to be found. But the special ones that ferment grape juice exist in extraordinary abundance in wine countries, for the same reason that we should find mildew germs in greatest number where they were being grown—*e.g.*, in the cupboard holding the mouldy boot or the mildewed crust.

What a terrible waste is this fermentation, which we see now is a kind of decay. Out of a pound of grapes, such as those before-mentioned, we should get at most 7 oz. of wine, or about one-third of a pint, containing 6 oz. water, $\frac{2}{3}$ oz. alcohol, 3 grains albumen, 20 grs. sugar, 10 grs. tartaric acid, 7 grs. acetic acid, 2 grs. ether, and 7 grs. mineral matter, besides a dye, and two or three other useless substances, in small amount. Amongst these the albumen and sugar alone can be rightly regarded as food.

Why do people so often fancy that such a mixture must be most nourishing, and have some wonderful charms about it? It is grape juice from which the foods have almost entirely disappeared, while a poisonous agent has taken their

place. Let us all strive to so understand this matter, that we may all be able to do something to dispel so disastrous a delusion.

We must now examine the chemical changes that occur during this fermentation, which is called vinous or wine-making fermentation. Grape sugar, frequently called glucose, consists of $C_6H_{12}O_6$, and is, in the growing plant, formed from starch, as described on page 60. For reasons that are difficult to grasp, except by the chemist, we generally multiply these numbers by two, and write down—Grape sugar=$C_{12}H_{24}O_{12}$. From this, four molecules of carbonic acid gas separate, and four of alcohol remain. It is usual to express the change in this way :—

Grape-sugar	=	4 carbonic acid gas	+	4 alcohol.
$C_{12}H_{24}O_{12}$	=	$4\ (CO_2)$	+	$4\ (C_2H_6O)$.

If you remember that the carbon atom weighs 12, the hydrogen 1, and the oxygen 16, it is not difficult to make out from the forms (formulæ) above, that 180 lbs. weight of sugar gives 88 lbs. of carbonic acid and 92 lbs. of alcohol, which will show how it is that 2 oz. of sugar in the grape only yield $\frac{2}{3}$ oz. of alcohol in the wine. A full oz. would be produced, but there is some waste, some sugar remains unfermented, and a little is changed, not into alcohol, but into glycerine, succinic acid, acetic acid, and ether. When 100 lbs. of sugar are fermented about 4 lbs. are changed into glycerine and succinic acid,

hence these latter substances are always found both in wine and beer.

Fruits of any kind containing sugar may have their juices fermented. So we have currant, elderberry, and gooseberry wines; indeed, gooseberries in their composition are a good deal like grapes, except that they only contain about half as much sugar and half as much nourishment generally. These wines are frequently called British wines, or home-made wines, and are sometimes fancied not to be intoxicating, or only so very slightly intoxicating that they might be regarded as *innocent*, but since our fruits contain less sugar than grapes, sugar is added to their juices, so that these actually become sweeter than grape juice. The fermentation changes the sugar into alcohol, as we have already seen, and the wine may really be more hurtful than that made from grapes. Many young people, through the ignorance of their friends over this matter, have been led into the saddest of mistakes.

Many "British Wines," and some not called British, are produced by the fermentation of rhubarb, which, when too stale for table use, is exactly suited to the purpose indicated. It then most easily ferments when placed together in quantity with sugar and water, by the multiplication of the fermentive germs accidentally found upon it, after the manner of the fermentation of grapes, or the souring of milk. The fermentation being completed, the whole result, now decidedly intoxicating, is pressed through strainers, and

after fining or clearing, forms the basis of a variety of wines made by colouring and flavouring.

Cider and perry are made from the juice of apples and pears respectively, and have acquired, like the other fruit juices before-mentioned, the bad quality of intoxicating through their sugar undergoing fermentation. Let us note in closing that the changes thus caused are not greater or more wonderful than others we have studied. The candle which a Lapland boy would eat, as we should sweetstuff, is changed by burning into a gas, which would quickly kill us. Water, which tallow refuses to touch, being the other product. The salt we eat can be divided by the chemist into a gas, chlorine, and a metal, sodium. The first is pale green in colour, of a most pungent smell, and would choke us immediately if we were to breathe it. The second, if put upon our tongue, would eat a hole through it in a few seconds, burning up and going off with a bang and a shower of yellow sparks. So then the alcohol although once a part of sugar, is in no way like it. Oh, if it had been, what miseries would have been saved, and what multitudes of sins that have disgraced the world would have been uncommitted.

CHAPTER IX.

Port Wine.

I AM very anxious that all should understand the nature of port wine, because there are still great numbers of people who believe it to be the best food and finest medicine we possess, while unfortunately some doctors, from not studying the subject as they should, recommend it in such a way as to help to keep up these foolish ideas.

FIG. 26.—GRAPE-GATHERER.

The port wine country lies in Portugal, on the banks of the river Douro, at the mouth of which stands Oporto, giving its name to the wine, which name we have now shortened into "port." The climate is delightful, and so warm, that the

orange and maize both flourish. The vines are cultivated on hill sides, and the grapes when ripe are mostly gathered by women, who bring the dark coloured bunches in large baskets (fig. 26) to the *lagar*, a structure which is not unlike a small swimming bath made of stone, and having perpendicular sides about three feet high. Sometimes two or three of these are placed under one long low pitched roof. At the end of each *lagar* and in communication with it, is a sort of cistern, and from this at a certain stage the half-made wine is carried by hand or by metal pipes to immense vats (fig. 27, Frontispiece).

A company of twenty or more men is selected to perform the work of crushing the grapes, tons of which have been gathered and laid in the *lagar* until it has been evenly filled. This filling is done carefully, for any needless breaking of the grape skins would start fermentation prematurely and spoil the wine by causing some at least of its alcohol to be changed into acetic acid or vinegar. When the mid-day meal is finished, the men make ready for their work in a manner that would much surprise and perhaps somewhat dismay many a port wine drinker. The feet are bared and the breeches tucked up when the men mount the stone steps which run along the side of the *lagar*, and "follow my leader" by jumping into it in rapid succession, crushing the purple fruit, and bespattering themselves with the rich juice.

Music is invariably provided to enliven the movements of the treaders who strive to keep

time singing in their native Portuguese as they raise one leg well in air, and then the other "right, left!" "right, left!" They at the same time place their arms on each others shoulders, and so get and give aid in keeping balance as they sway about, sinking more than knee deep into their purple coloured bath. While this operation is in progress, keen watch is kept by overseers so that none shirks his proper share of the labour which is not only irksome but wearying.

The first treading is carried on through the night, as it lasts, with occasional changes of men, for eighteen hours, when the grapes are pretty well crushed. After an interval of rest the men are often encouraged to renew their task by a drink of brandy and a cigarette, which is smoked while dancing in the future port wine of the epicure. The stalks and pips now at the bottom can form no very agreeable pavement, but the habit of doing much without boots so common in the wine districts makes the suffering possibly slight; but, depend upon it, many a poor toe gets sadly scratched and sore before the wind-up of the season, which lasts at least three weeks, the grapes not all ripening at the same time.

You would be much amused, but perhaps a little shocked could I show you a picture I have of a man holding a saucer for a tasting sample of the *must*, which one of the treaders is supplying by holding up his leg and allowing the liquid to drip from his heel.

By the time the treading is completed, a violent fermentation has commenced, and is allowed to continue a shorter or longer period according to the ripeness of the grapes, the temperature of the air, and the intention to change all or only a part of the sugar into alcohol. During the fermentation, as we learnt last chapter, the stalks and skins are carried to the top and form a thick cover having a name meaning "the hat," this prevents the air getting into contact with the must, so that the wine is not converted into vinegar as, we have previously remarked, it otherwise certainly would be.

When the wine-maker concludes that the fermentation has gone far enough, the liquid is run off through a rough strainer, often a basket, into the side cistern before-mentioned, whence it passes by pipes into large closed vats, should these be, as is very general, placed below the level of the *lagar;* sometimes they inconveniently stand on the same floor, as in fig. 27 (Frontispiece), then the liquid has to be carried or pumped up to them. The remainder, consisting of stalks and skins, is afterwards pressed, and the result added to that already in the vats.

Fermentation will continue in the vats, although it will be more and more languid until all the sugar has disappeared, when, for want of food for the ferments, it will stop. Wine deprived of all sugar in this way is called "dry." If it is desired that the wine should remain sweet, between 5 and 10 per cent. of brandy, half of which

is alcohol, is added. The quantity of alcohol now present is so great that it kills the ferments and stops fermentation. In this way the remaining sugar is saved from change. These sugary wines are called "fruity," or sweet. When the amount of alcohol reaches 16 per cent.* the ferment dies. Should any wine contain more than this it is certain that alcohol has been added, and then the wine is said to be fortified. Practically, all port wines, and all sherries have been strengthened or fortified by the addition of alcohol in some form. There are two reasons for this, besides the one already given. (1*st*), Port wine will not *keep* and *travel* without additional alcohol. What nonsense it is to talk of wine being a natural product. It is artificial at every point. (2*nd*), The English taste is in favour of fiery and strongly intoxicating wines, and alcohol is specially added to such as are intended for the English market.

When the wine has become still, and carbonic acid gas is no longer formed, the bungs are driven in tightly, for without this precaution air would then enter and begin the work of vinegar-making. During the winter the wine is run off into large casks called pipes.

The process described is that of making the very best port, and you naturally ask why such an extremely dirty method of pressing the grapes

* The limit of 16 per cent. is never reached in actual manufacture, 13½ per cent. is the largest amount of alcohol that natural —*i.e.*, unfortified, wines contain.

should be adopted.* The answer is that machinery is *not* used lest by any means the seeds (stones) of the grapes should get bruised, for they contain a badly flavoured oil which would escape if they were broken, and so, it is said, spoil the wine. We, most of us, should think the remedy much worse than the disease, but this is a question we can well leave to the taste of port wine drinkers. This port is considered to be most nutritious, but it cannot be. It does not possess the right material for nourishing the body. The albumen and sugar have almost vanished, and these are in truth the foods the grape contained.

It is the chemist after all who must settle this question, and of him we learn that first-class port on an average contains in each pint about 3½ oz. of alcohol, mingled with 16 oz. water. He finds besides tartaric acid, 24 grains, and acetic acid, half as much; both of these substances being regarded as objectionable, and every effort is put out by the wine maker to reduce their amount. Mineral matters reach 20 grains; ethers, which contribute to flavour and odour, 6 grs.; sugar, ½ an oz., and albumen, 10 grains. The last two, as has been already said, are foods,

* Many foods are not prepared so delicately as might be desired, but the wine industry appears to carry the palm in this matter, for in parts of Burgundy the unfinished wine "receives an energetic stirring by men who enter the vats quite naked, and work about in the mixture with body and limbs. This most objectionable practice is now happily on the decline."—*Thudichum and Dupré*, p. 111. I am sorry to add that port is sometimes similarly treated.

the first a heat, and the second a flesh former; but their amount is such that there is no exaggeration in stating that half-a-pound of sugar and a hen's egg contain rather more nourishment than a dozen bottles or two gallons of this boasted and expensive wine.

Port is probably thought by the ignorant to be so nourishing because of its red colour, but this colour is perfectly useless to the body, and is derived from the grape skin. The pulp is nearly white, but the skin, which we refuse when we eat grapes, is strongly purple. As alcohol begins to be formed in the *lagar*, it dissolves out the dye of the skin, and so reddens the wine. If the skins be separated before fermentation, then dark grapes will produce a light wine. It frequently happens that the grapes will not give a good colour, and then dried elderberries are used as a stain.

Port wine also contains tannin, the value (?) of which is often most ridiculously exaggerated. This is the very substance which, found in oak bark, tans hides into leather, and which has a rough and bitter taste. It exists in the bark of the grape stalk, and escapes into the wine during the fermentation, just as the dye leaves the skins. This gives the port wine drinker occasion to tell of "the tonic quality," "the beautiful roughness," "the delicate astringency," of his chosen liquor. Poor teetotaller! What are *you* to do? Where are *you* to get these fine things? Blood-red colour and delicate astringency! Be comforted, you can have them if you will. When you take

grapes, eat the skins and chew the stalks, and both will be yours; while you will also get all the albumen and all the sugar, but be sure not to bite the stones else you will taste the badly-flavoured oil. Cheer up, the laugh is entirely on your side after all.

Very much might be said of the imitation port wines turned out by the class of port wine makers, one of whom is seen in fig. 28. These, with dyes, bad alcohols, ethers, and chemicals more or less injurious, manage just to suit any and every fancy. It is perfectly well known that these imitations, which are not made from grapes at all, are produced in such immense quantity that it is certain the majority of people get them instead of actual port. Some of them are terribly injurious, but instead of occupying time in describing them I prefer to show that even the genuine wine does not in the least deserve the good character that has been given to it, and to add that some of our greatest doctors are now saying "the common notions about port wine form one of the most extraordinary delusions of the present day."

FIG. 28.—PORT WINE (?) MAKER.

CHAPTER X.

Ale and Beer.

We have seen that the alcohol of wine is produced by a ferment dividing sugar into two parts. We have now to remember that all the alcohol of every kind of intoxicating drink is formed in a similar manner, sugar always being its actual source.

Beer is chiefly made from malt, while malt is made from barley, each grain of which much resembles the wheat grain (fig. 20), in that it is a store of nourishment to feed the little plant (the embryo) which lies at the base of the seed (c, *e*). The nourishment is almost all in the insoluble form of albumen* (which we shall sometimes call gluten) and starch, and so quite unsuited to the purposes of the brewer, whose object is not to provide nourishment, but a liquid intoxicant that will keep well. For the latter purpose he is obliged, during the process

* Albumen is the common name for the white of an egg. The substance found in the wheat grain, which closely resembles the latter in composition, is called either albumen, gluten, or vegetable albumen. It lies in the aleurone granules (page 63).

of manufacture, to destroy or remove almost all the vegetable albumen or gluten of the grain, and for the former the starch must be changed into sugar. To suit the brewer, by the production of sugar, the barley is passed through two processes, which are called malting and mashing, and are managed as follows:

The maltster (or malt maker) introduces us to a large dimly-lighted and low-roofed building, having usually a slate floor. At the end is a large tank half full of water. Into this the barley is put and allowed to remain about fifty hours, which soaks each grain to the very centre. It is now removed with large wooden shovels and placed in a heap on the floor, a new lot of barley taking its place in the tank.

Fig. 29.—Maltster at Work.

The heap soon begins to grow warm, for changes are commencing. The grains are making ready to grow and produce new plants, and as no work can be done without using up material, the grains are absorbing oxygen, and forming carbonic acid. This causes the heat (see page 52). The

men who have to watch the process spread the heap out on the floor, as seen in fig. 29, before the heat becomes great enough to kill the grains. Here the growing continues, the gluten in part being altered into a soluble substance called diastase, which has the very curious power of acting on the starch of the grain, and changing it first into gum and then into sugar. During the growing, little by little, the starch is changed by the diastase, as the plant requires new food. Constant attention is given during from twelve to fourteen days, when a little root has grown out from the embryo about half-an-inch long, and the budding leaves or acrospire (*l*, fig. 20), have pushed up under the skin or case, and altered the shape of the barley from *a* to *b* (fig. 30). It is now called malt, and is of course more costly than the barley from which it was made, while its food value is reduced, its weight also is lessened by one-eighth, which is increased to one-fifth when the excess of water it now holds is driven off. Only a very small portion of the starch has as yet been changed into sugar, but the diastase has been produced, and this is the real object of malting, which should be carefully noted, as mistakes about this point are very general.

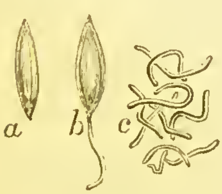

FIG. 30.
a. Barley Grain.
b. Malt Grain, with Rootlet.
c. Rootlets, or Sprits.

The growth is now stopped by drying in a

kiln, having a shallow fire. For pale ales, great care is taken to prevent the malt being in the smallest degree scorched. For ales of darker colour, drying is performed more quickly at a higher temperature. The malt is separated from the burning Welsh coal, usually used for heating, by two frames of wire gauze. It is spread upon the upper one, and turned over two or three times during about twenty-four hours. Those grains that in the course of the turning are unfortunate enough to tumble through the upper frame get burnt black. They are not, however, wasted. Under the name of black malt, they give virtue to porter and stout,* colouring them with their burnt juices. What a mistake those make who think that blackness always means richness. Here it means charcoal.

The malt is next screened to sift from it the little roots (*c*, fig. 30), called sprits, which make a capital food for cattle. These sprits are separated for a very instructive reason. They are so rich in albumen, in other words, are so highly nourishing, that the brewer must not use them, or they would, by giving albumen to the beer, hinder its keeping qualities.

The maltster has increased the price, and decreased the worth of the barley, but now the

* "Nourishing Stout" is now frequently coloured and thickened by the use of a half burnt sugar and gum, which as sold, is intensely black and very sticky, having much the appearance of lumps of pitch coated with tar.

brewer does far worse with the malt. He first crushes it, and then puts it into a very large vessel, called the mash-tun (see fig. 31), which is filled with water at about 150° or 160° Fahrenheit (see fig. 37), where it is kept hot for five or six hours, and continually stirred by rakes moved by machinery, which turns the spindle (*a*). You may think that this long hot soaking is to get all the goodness out of the malt. This would be a *great* mistake. It is to give the diastase time to turn the starch into gum* and sugar, principally the latter, so that it may dissolve out into the sweet wort, as the liquor is now called. The brewer only desires to soak out a small part of the albumen, and do not imagine that he intends even *that* for the customer who buys the beer. No, it is not for him at all, but to feed and keep up the strength of the little ferment, whose work is to produce the alcohol and destroy the albumen at the same time. To

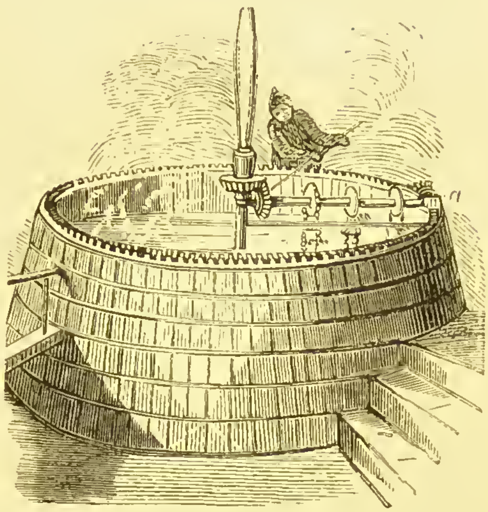

FIG. 31.—MASH TUN.
a. Spindle turning Rakes.

* This kind of gum is called dextrine, sometimes malt gum or British gum.

prevent more than the very little the ferment requires, escaping from the malt, he uses water made artifically hard by adding to it Gypsum, which may be called sulphate of lime, or plaster of Paris. Burton ales owe their good (?) qualities largely to the hardness of the Trent water, which reduces the quantity of albumen made soluble in mashing, and it is interesting that in the making of sherry, Plaster of Paris is sprinkled over the grapes before treading, often to a considerable amount, in order that only a fraction of the albumen of the grape may find its way into the wine, the potash of the grape juice is thereby changed into sulphate of potash, a highly objectionable substance. This practice is called plastering, and is certainly in the case of wines very injurious. It would be well if those who believe in alcoholic drinks as highly nourishing, were to give attention to these things, and *we* should strive to so understand them that we may hereafter explain to our fellows, and thus perhaps save some from the destruction that intoxicating drinks frequently cause.

When the sweet wort has been strained away from the crushed and soaked malt, now called grains, which are given to the cow, the brewer boils it with the blossoms of the hop-plant,* or

* The hop has not always been in favour. Early in the seventeenth century, the City of London petitioned Parliament against "Newcastle coals, in regard of their stench, and against hops in regard they would spoil the taste of drink and endanger the people."

some other bitter to prevent it turning sour. The liquor thus produced contains a great deal of sugar and gum, a bitter from the hops, and a small quantity of albumen. It is, at this point, not at all intoxicating; has a sweet mawkish taste, and is light brown in colour if pale malt alone has been used, and then it will brew into ale. If black malt was added in the mashing its colour is dark, and porter or stout will be the result. Its nourishment is nearly all in the sugar, and this the next step will destroy.

The liquor is now cooled as quickly as possible and run off into the fermenting vat. Here it would, if left to itself, ferment in the same manner as grape juice, because alcoholic ferments would fall into it from the air and multiply. Not these *only*, however, for the very kinds that changed the milk and the beef-tea, and that mildewed the boot and the bread would fall in also. Therefore, besides alcohol, which would change quickly into vinegar, the fermenting vat (if left to itself as we are supposing) would contain a queer mixture holding in it lactic acid and the bad products formed by the decay of the albumen; but singular as you may think it, the mildew germs, the same that served the boot so badly, would develop alcohol, about which more will be said presently.

The brewer of course desires alcoholic fermentation only, and so he starts this as rapidly as possible by adding yeast, which is a good deal like cream in consistency but darker in colour.

It is made up of countless millions of living alcoholic ferments with a little fluid between them. These get to work at once; multiply and cover the forming beer with a froth, so that the other ferments get little chance.

We must now study somewhat carefully the nature of this yeast. If we take a very small quantity of it, add water, and then look at it in the microscope, we see small oval bodies,

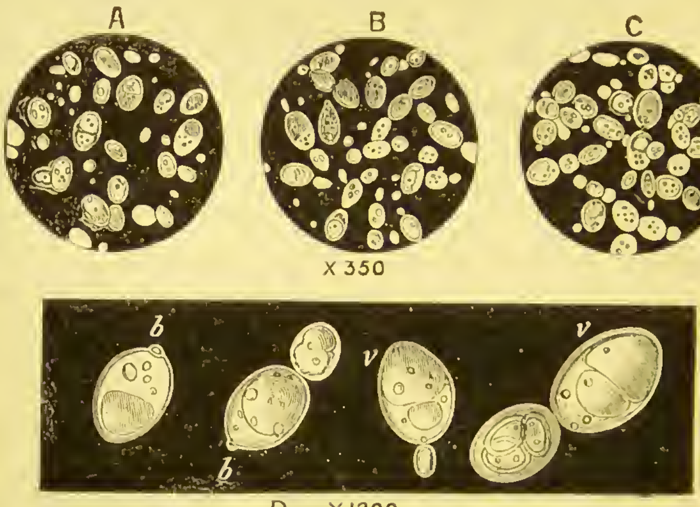

FIG. 32. —YEAST CELLS, TORULA CEREVISÆ.
A. Cells at Rest; B. Cells Growing; C. Cells in Chains; D. Cells very highly Magnified, *b.* Bud, *v.* Vacuole or Watery Space.

as at A, fig. 32, which are generally separate. If we now place in a tumbler one-third full of water two or three lumps of sugar and a very small quantity of white of egg—*i.e.*, albumen, we have a fluid in which yeast cells, as these little bodies are called, can grow, because sugar and albumen form their food.

Adding now a drop of yeast such as we have examined and stirring well, we place the tumbler in a warm room and leave it three or four hours. Small bubbles will rise, consisting of carbonic acid gas, and alcohol begins to be formed. We now make another examination, and find the appearance as at B. The cells have budded at the ends, and these buds have increased, until they have become as large as their parents. The cells sometimes contain small granules, looking like dots in the microscope, and these are occasionally moving rapidly about. In three or four hours more, the cells will have increased by further buddings, until chains of four or five, C, fig. 32, or more, are formed. Because the yeast ferment forms chains in this way it has been called "Torula," from a Latin word meaning a rope in knots.

The process of budding is seen more clearly by very powerful glasses, as at D; *b.b.* showing the beginning of the bud, and *v.v.* watery cavities, or vacuoles, frequently found in the cell when at rest. I have made these drawings from actual cells, that you might understand how curiously they change. Yeast cells act in very similar manner to the wine ferment (described at page 80), to which they are first cousins, or even nearer relatives. They are somewhat larger, yet so small that 250,000,000 would only be equal in bulk to a drop of water. They in common with ferments generally, produce a considerable rise in temperature when a great mass of them is grow-

ing together. The fluid in which our experiment is performed is too small in quantity to show any increased heat, but it will froth visibly, and become alcoholic in smell. In a few days the alcohol will have been changed to acetic acid, and we shall have vinegar.

The formation of carbonic acid gas and alcohol, by yeast, can be easily experimentally proved in the following way:—

Make the same mixture as before, but place it now in a flask, *f*, fig. 33. Pierce the cork, and pass through it a bent tube. Take a tub or pan, *t*, and place in it an inverted flower-pot, the side of which has had an opening knocked through it by repeated smart taps with a light hammer.

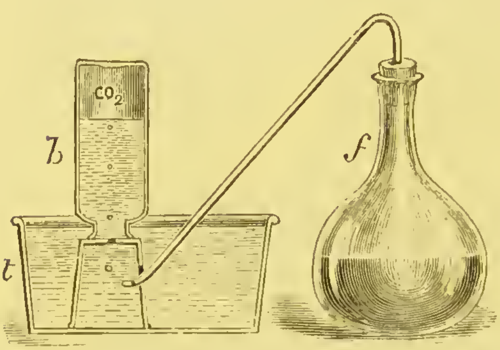

FIG. 33.—GENERATING CARBONIC ACID GAS FROM FERMENTING SUGAR.

Fill nearly with water, and stand a bottle, *b*, also filled, as in the figure. As CO_2 is formed, it will pass over in bubbles, and collect as represented, although some of it will be lost by dissolving in the water. When the bottle is full, it may be tested by a taper and by lime-water, in the manner already fully explained in Chapter IV., with which you are now familiar. The alcohol formed in the flask (*f*) will not now change

into vinegar, because CO_2 is over it, and not common air. When the process is finished we may remove the flask and tube, and distil (see Spirits, page 121) the alcohol over, by heating the flask over a spirit lamp. The alcohol can then be lighted as it escapes at the end of the tube.

Our experiments will enable us to comprehend what occurs in the fermenting vat of the brew-house, to which our attention must now be

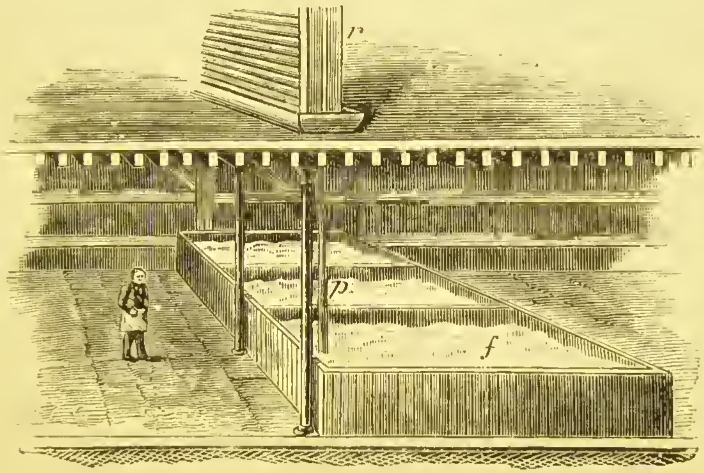

FIG. 34.—FERMENTING VATS.
r. Refrigerator; *p*. Pipe Conveying Sweet Wort; *f*. Yeast.

given. We remember that the sweet wort had been rapidly cooled. It is then often passed through a pipe (*p*, fig. 34), from the refrigerator (*r*) in an upper floor. So soon as the fermenting vessels are filled sufficiently, a quantity of yeast is added, and within a few hours, sometimes more quickly, according to the season of the year and the state of the yeast, the whole commences to

"work." The commotion is considerable, the temperature goes up, and millions of tiny bubbles rise to the surface, forming a dense, creamy froth (*f*), several inches thick.

The progressive changes of the fermentation may be summarised as follows :—The albumen is being consumed and the sugar eaten by the yeast, while the carbonic acid gas and the alcohol are being turned out by the ferment, which thrives and multiplies. The process continues sometimes as much as six or eight days, the yeast* increasing meanwhile five or six, or even eight times, and so providing the brewer with material for fermenting succeeding lots of sweet wort. The ale or beer is now drawn off from the yeast, and the fermentation slowly comes to an end. It is next racked off into casks for sale, and bunged tightly down so soon as it is still enough to make the operation safe. Strange that so many are ready to buy, for the fourpenny worth of barley for each gallon has been soaked and malted and mashed and fermented, until its virtues are almost gone, and now two shillings must be paid for it. What does it do for the money? It is not our business yet to follow it, and trace the headache, the heartache, and the ruin it too often causes, for the story of the brewhouse is not yet all told.

* The excess, after being partially dried, is usually sold for use in spirit making, as the large amount of alcohol in distiller's wash (see page 124) nearly destroys the yeast germ, so that the distiller is a consumer and not a producer of yeast.

CHAPTER XI.

The Brewers' Exhibition.

The ales and beers we have been talking about are "Genuine malt and hops," as people say: the very things they suppose that make it certain that the beer must be all that can be desired. We can now judge for ourselves about the value of "genuine malt and hops;" but do not suppose that all beers are made exclusively or even principally of these substances.

About seven years since, having heard from a friend that at the Brewers' Exhibition, then being held in the Agricultural Hall, London, there was some mystery, as the public were prevented from entering a part of it, I lost no time in visiting the place. The huge building was nearly all occupied with every kind of article brewers could be supposed to require, from a vent peg to a fermenting vat, while malt, hops, sugar, and gypsum were freely displayed; but none of these things delayed me long, not even the half-pint glass which, it was confidentially suggested, ran five to the quart, for at one end, behind a large and attractive stall, was a separate apartment,

concealed by framing and curtains, before which stood a large and conspicuous announcement—

NONE BUT BREWERS ADMITTED.

The cook ought to have no secrets : all that we are asked to eat and drink ought to be open and above-board. Feeling, therefore, that I had a right to enter, I determined to do so, unless forbidden, for had I been challenged, I should have made no concealment. It was evident that if anything which threatened damage to health were being exhibited, justice demanded that it should be exposed, but, if nothing damaging, there was no need for secrecy. Under these circumstances, I specially desired to secure for myself an invitation to pass the barrier, and such I received, as you shall now learn. At one end of the public part of the stall was a gentleman with two microscopes. I commenced conversation with him by asking him if he were exhibiting specimens of *torula cerevisæ*, which is the name given to the yeast plant by scientific people. He replied that he was. I told him *I* frequently grew specimens, when he asked me to examine his, in order that I might give an opinion. They were, as you might suppose, perfect from the brewer's point of view—*i.e.*, they contained no other ferments than the very one that will produce alcohol, and brewers find this an extreme

difficulty. The ferments* that cause different kinds of decay get constantly into and multiply along with the yeast, and so more or less spoil the sweet wort. Our conversation was continued upon scientific points; my courteous entertainer, for such he had become, showing me a number of plans by which he was endeavouring to get yeast free of all impurities. Then he added, you must not go until you have seen "Our Converter." "The very object I had in coming," I replied, for I knew that the converter was the apparatus behind the placard, to which I have already referred.

The curtain was lifted, and I was put into the charge of a young man, who was to explain everything to me, as I was "interested in the scientific side of brewing." You will admit that this description of myself was exactly true. I was then duly informed that the apparatus before me, which seemed half steam-engine, half copper-boiler, was intended to "convert" all starchy matters whatever into material for brewing first-class beers. So that spoilt rice, granary sweepings, and a long catalogue of similar bodies were available. The starchy matters are simply changed or con-

* Here it is worth noticing, that mildew germs getting into the wort produce alcohol like yeast; and Mr. Horace Cheshire, in some new investigations, has recently arrived at very curious results, in which he seems to show the closest relationship between yeast and mildew, and make it even quite doubtful whether they are not after all but different conditions of the same thing.

verted into sugar, and then this, by the action of yeast, produces the alcohol in the usual way.

But how are these starchy matters changed into sugar? We have only yet seen that the living plant and diastase can do this. Sulphuric acid has the same power, and it really possesses it in a very high degree. It is used in "The Converter," and in order to understand the latter, we had better give our attention to an experiment.

Put into a glass beaker (*b*, fig. 35), or into an enamelled saucepan, six tablespoonfuls of water and thirty drops of sulphuric acid: Mix a tablespoonful of starch with some water, until it forms a paste: Bring the acidulated water to a brisk boil, and then add the starch paste little by little, so as not to interrupt the boiling, and continue to stir, boiling the mixture, as represented in the figure, for at least ten minutes. Instead of the materials becoming thick, as you would suppose, they remain quite liquid, for instead of having starch* paste, we have now sugar, formed by the action of the sulphuric acid on the starch and water, with which the acid remains mixed. If we add powdered chalk (or

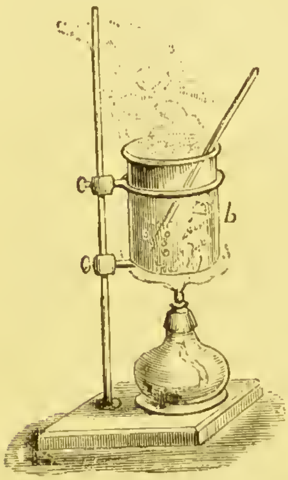

FIG. 35.
CONVERTING STARCH BY SULPHURIC ACID.

* Much of the starch may be only changed into gum if the boiling has not been continued long.

carbonate of lime), its carbonic acid is driven off by the sulphuric acid, as it would be driven from carbonate of soda (see page 40), the acid uniting with the lime, forming sulphate of lime, or gypsum, which, scarcely dissolving at all, can almost entirely be got rid of by filtering.

Let us now return to the "converter." The waste starchy bodies before referred to are soaked for twenty-four hours in a bath containing sulphuric acid 1 part, water 100 parts. The whole is then placed in the converter, a large pear-shaped vessel of copper, having around it a case, into which exceedingly hot steam (high pressure steam) can be blown from a boiler. The entrance of the steam heats up the contents of the converter above the boiling point, and in five or six minutes no starch remains—all now is either gum (dextrine) or sugar.

When the operation had been completed in my presence, the sugary fluid and grain were run out and treated with powdered chalk, when a fizzing, shaming the most violent ginger beer, occurred; after this, the fluid was filtered, and a glass handed to me to taste. I cannot say I enjoyed it. It was a mawkish, syrupy liquid, of a light brown colour. It was indeed a sweet wort, from which by yeast, as we saw in the last lesson, beer could be made. I now asked one or two questions, to which answers were given in a manner that showed they were regarded as great secrets, I never thought them such, and since they may be useful I tell them to you. I said,

"But does beer produced from converted starch satisfy the customers, equally with that produced from malt?" "Oh, certainly," was the reply; "there is one brewery near Birmingham where they run a double plant,* one using the usual mash, the other our converter. The customers receive the beer, knowing nothing whatever of the side of the brewery whence it comes." Then said I, "About cost?" "That is the important point," was the reply. "I can assure you, sir, if you will use our converter in your brewery, you will save 4s. a barrel." This did not tempt me, for having no brewery, and no barrels, I only use the converter to show those who believe in genuine malt and hops, that they are trusting to a fancy.

Do I condemn the converter? By no means more than I condemn all brewing. The alcohol made from its sugar is as good and as bad as any other. Tens of thousands of tons of sugar made by the same kind of conversion, are used yearly in British brew-houses. Maize or Indian corn is in America exceedingly cheap. It is treated much as I have described. The syrup, formed from it, is boiled down and formed into blocks of sugar, which resembles that of the grape, excepting that it contains a proportion of gum which the brewers desire, because it gives thickness to the beer which they call "body." Whole shiploads of this are brought to England, and sold under the name of Saccharum, the Latin word for sugar. It is added to the

* Plant, a set of machinery.

sweet wort made from malt, and so befriends the brewer in two ways—first, by reducing cost; and next, by reducing the relative amount of albumen the sweet wort holds, and this tends to improve the keeping qualities of the ale.

The brewer sometimes gains these two advantages in another way. Along with malt he uses barley in the mash tub. The barley has its starch changed into gum and sugar by the diastase of the malt with which it is mixed, but practically it adds no albumen, as that remains undissolved in the grains.

Before closing this subject we ought to become acquainted with the actual materials found in the so-called malt liquors. They are very complicated bodies, and I will start by taking Bass's pale ale, which you know is rather expensive, as an example. In one pint, which weighs a little more than 20 oz., we find, on the basis of an analysis given in the Food Collection of the Bethnal Green Museum,—Water, 8284 grains; Alcohol, 449 grains. The remainder, only 400 grains, made up of a large number of bodies, principally three, which, we honestly say at once, act as a food—these are, dextrine, or British gum; sugar, and albuminoid* substance. The first two of these are heat producers; the last would build up the body, but its amount is only a few grains. Then comes a list of either unimportant or injurious substances, consisting of burnt sugar, glycerine, acetic acid (the acid of

* Resembling or like albumen.

vinegar), lactic acid (the acid of sour milk), carbonic and succinic acids (both of which are being constantly formed as waste products in our own bodies), resin, tannin, an essential oil from the hop, salt, gypsum, or plaster of Paris, &c. London porter, generally esteemed so extremely nourishing, really contains rather more water than Bass's pale ale, with a little less alcohol and less bitter, while it has more gum, and much

FIG. 36.—COMPARISON OF PALE ALE AND LONDON STOUT, SHOWING NUTRIMENT IN EACH.

dark colouring matter from the burnt or black malt. The weight of one pint, taken as a sample by Professor Church, in the Food Collection before-mentioned, is 9209 grains, of which 8287 grains are water, and 447 grains alcohol, the remaining 475 grains are made up of the same list of substances as already given for the pale ale, although the proportions are different. Fig. 36 shows in true relation the composition of the

two liquors we have been considering. The outer light space represents the water, the black ring the alcohol, the thin white circle the acids and earthy matters within which lie the foods—heat formers the black ring around and flesh formers the white circle at the centre.

The effect of these drinks on the body, we shall consider in a later chapter. The diagrams show how little nourishment they have in them. The amount in a gallon of ale, costing two shillings, being considerably less than that contained in a pennyworth of bread.

There are two reasons why these drinks are consumed so largely. People like them, and they contain alcohol. For who would not laugh at calling such mixtures foods, if his mind were not clouded by the fact that alcohol is in them. But the most terrible mistakes are common. Even Mr. Disraeli, in the House of Commons, called beer "Liquid bread"! How much our rulers, most of them, need to learn on this question!

Some may wonder how glycerine gets into the beer. The cause is mentioned in Chapter VIII., but it is well to state here that it is because the yeast plant does not change all the sugar into alcohol and carbonic acid gas. It changes about $\frac{1}{25}$th part of it into glycerine and succinic acid.

The acetic acid is produced not intentionally but accidentally; for as I have more than once said, alcohol would be changed into vinegar during

the making of wine or ale, if it were not kept from the air. A fraction of the alcohol is unavoidably always so changed, accounting for the acetic acid mentioned as existing in Bass's pale ale. Without due precautions, such as careful bunging or keeping a vent peg in the cask so as to exclude the air as perfectly as possible, the whole of the alcohol would by degrees become acetic acid, making the beer at first sour, and finally producing from it a muddy vinegar, which would be absolutely non-intoxicating, as in the case of our experiment (see page 104). Without doubt a particular kind of ferment—the *acetic* having a considerable resemblance to the *torula* or alcoholic ferment, but which, unlike the latter, cannot live without free oxygen, is the instrument in producing the change. The chemical view of the process may be explained and represented thus:—Alcohol (see page 84) consists of $\mathbf{C_2\ H_6\ O}$, and if exposed when diluted with water, to the action of oxygen, especially while warm or during alcoholic fermentation, one atom of oxygen joins it, while another runs away with two hydrogen atoms, forming water, and converting the alcohol into acetic acid.

$$\begin{array}{ccccc} \textbf{Alcohol} + & \textbf{2 Oxygen} & = \textbf{Water} + & \textbf{Acetic Acid.} \\ C_2H_6O + & 2O & = H_2O + & C_2H_4O_2. \end{array}$$

Beer is liable to adulterations, some of which are doubtless pernicious, although now such are possibly only very occasionally employed in consequence of the heavy fines inflicted in recent

years where drugs dangerous to health have been discovered. Hop bitters are used frequently, and in some breweries regularly, the term meaning any kind of bitter not exclusively hops. Quassia is the most general substitute, and this possibly is not more injurious than hops themselves. Heading powders for causing frothing are eonsidered by many the correct thing. The retailer also, like the brewer, not infrequently endeavours to increase his profits by mild doctoring, henee water is added, to whieh we shall offer no objection, exeept that the addition is a dishonest act. It certainly does not harm the health although it may deceive the eustomer. A very common adulterant is salt, which is said to bring out the flavour of weak or diluted beers, but it is doubtless frequently intended to produce a craving for more drink in the frequenters of the beer-shop.

The damage caused by ales and beers does not arise from adulteration, but from the alcohol they contain. Genuine malt and hops, if always obtainable, would not lessen the mischief arising from beer-drinking. The poverty, disgrace, and agony they bring in their train we never can fully imagine. By always refusing these liquors we not only save ourselves from the mischief they infliet, but by example we help others to do likewise.

CHAPTER XII.

Spirits.

Spirits so-called from the large amount of spirits of wine they contain, are the most pernicious because the most alcoholic of the intoxicating drinks. The name ardent spirits is frequently applied to them from the Latin word *ardeo*, to burn, in consequence of their hot burning taste. The most common of them are gin, brandy, whisky, and rum, but there are many other kinds used in foreign countries. All, however, are alike prepared from liquids that have been fermented in the manner of wine or ale, and so have become alcoholic. The process by which they are produced, and which distinguishes them from other intoxicants, is called distillation, and consists in condensing the steam or vapour which arises from alcoholic liquids when they are heated. This, as we shall see presently, consists very largely of alcohol, which thus gives to distilled liquors their very intoxicating character.

Whilst making soup or warming milk, if the lid of the saucepan be lifted it will be seen to be covered by beads of water, all of which are clear

and bright. It is the water only of the soup or milk that goes off in the steam. In a similar way, although water contains usually a great deal of limy matter, the steam, made when we boil it, contains none, and so the tea kettle retaining all the lime becomes covered with furr. Could we put a long tube over the spout of the kettle so as to cool the steam, and condense it into water, which would drop from the end of the tube, the water would be said to be distilled. A method resembling this is frequently used when water of great purity is required, though of course a larger and better arrangement than a kettle and tube are employed to make it.

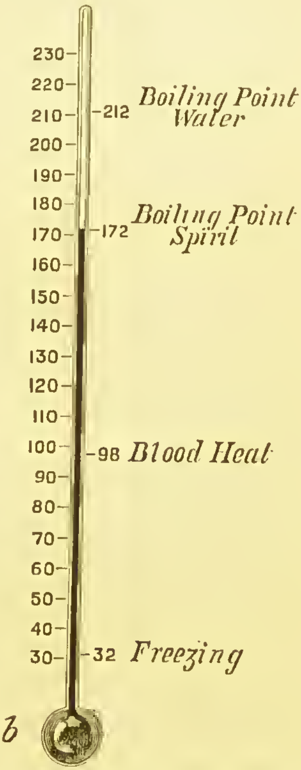

FIG. 37.—FAHRENHEIT THERMOMETER.

The vapours that rise from the salt sea, the fresh water lake and the muddy pool are all alike free of everything with which the water had been mixed, and so Nature is constantly carrying on a kind of distillation the broad world over, giving us the pure water that falls from the clouds in raindrops.

Water under ordinary conditions boils at about

212°* Fahrenheit thermometer. The thermometer is made of a fine tube of glass, at the end of which is a hollow ball or bulb (*b*, fig. 37), and in this is enough quicksilver (occasionally alcohol) to quite fill the ball, and a part of the tube. When the quicksilver is made hot, it swells or expands, and is obliged therefore to rise in the tube. By the side of this there are figures which tell us the exact heat or temperature in degrees. If the thermometer be put into boiling water the quicksilver rises and stands opposite 212°, and there it would remain all the time the water is kept boiling, but if spirits of wine or alcohol be made to boil, the thermometer would show that its heat was only 172°. From which we learn that alcohol boils at a lower temperature than water.

Mixing equal measures of alcohol and water the liquid boils at 182°, when as we might suppose a great deal of alcohol goes off in the vapour and only a little water, for the temperature is above the boiling point of alcohol, and below the boiling point of water. Could we condense this vapour we should get a liquid which would be much more than half alcohol, while that remaining behind would of course be more than half water.

* The little mark ° is read degrees. 3° = 3 degrees. There are also centigrade thermometers in which 100° marks boiling point, but since 100° centigrade is the same as 212° Fahrenheit, it follows that the degrees on the two thermometers are of different values.

Placing now some port wine in the retort (*r*, fig. 38), and bringing it to the boil, the alcohol with a little water will pass off in vapour. To prevent this escaping the tube of the retort is passed through the neck of a condenser (*c*) which is stood in a basin of cold water (*b*). The vapour in losing heat becomes fluid and collects at the bottom of the condenser. The water in the basin is, however, quickly heated. Should it be necessary, cold water may be poured on to the condenser, or soaked blotting-paper may be put over it, when evaporation will keep it sufficiently cool. We have now distilled over the alcohol, which is colourless as well as bright. The ethers and those acids of the port wine (see page 92) which boil at as low or a lower temperature than water, have come over with it, besides these we have a good deal of water in the condenser, which now, in fact, contains brandy of the very highest quality, but which is all but colourless. Burnt sugar may now be added to give it the tint which is considered correct.

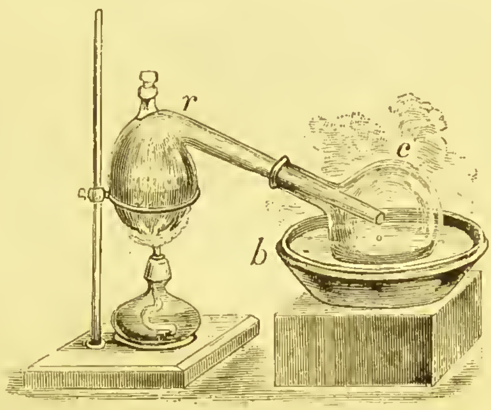

FIG. 38.—DISTILLATION.
(*r*) Retort; (*c*) Condenser; (*b*) Cooler.

It must not be imagined that brandy is often

made from port wine although very bad and rough samples, not being easily marketable, are sometimes distilled to produce it. Such brandy is mostly used for fortifying port as described in the ninth chapter. In France it is distilled from inferior wine flavoured with dried plums, and sweetened with sugar. Foreign brandy should be produced after this manner, our English word

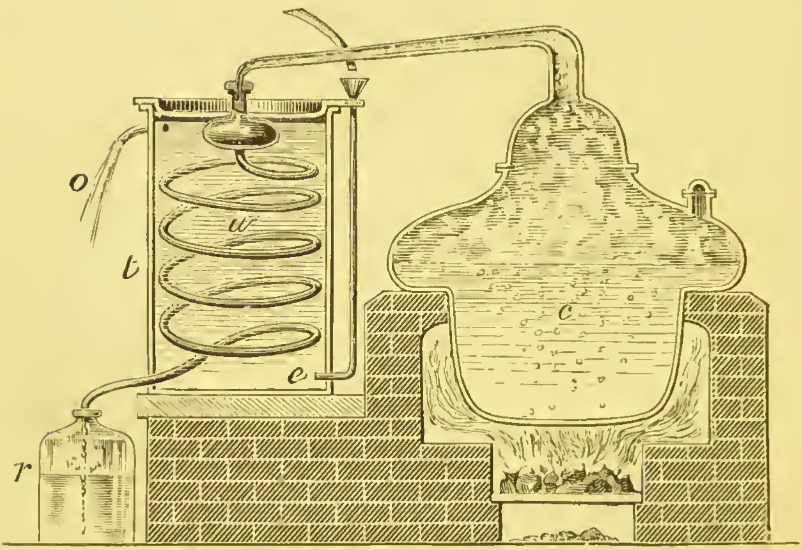

FIG. 39.—SMALL STILL.

(c) Cistern; (w) Worm; (t) Cooling Tank; (e) Entrance for Cold Water; (o) Outlet for Ditto; (r) Receiver.

being a corruption from the German, meaning burnt wine. Immense quantities of brandy are made in England, but far cheaper materials, as will be more fully explained, are employed for the purpose, while the apparatus is more effective than that used for our little experiment.

We see the general structure of a small still in

fig. 39. The liquor to be heated is placed in the body or cistern (c) and brought to a gentle boil, the vapour rising is carried through a long spiral metal pipe called the worm (w). The worm travels through a tank of water (t).. The water, as cold as is obtainable, is admitted beneath, where the distilled spirit is already cool. Rising as it gets warmer it flows away at (o), while the spiritous liquor drops into the receiver (r). In some distilleries complicated plans are followed to save fuel to the uttermost—*e.g.*, the vapour first passes through a closed tank of wort, which later on has to be distilled. By this the wort is made hot, and less coal is required to bring it to the boiling point, when it is transferred to the still, but our spaee will not let us dwell too long on these matters.

In dealing with ales we spoke of the changes wrought in barley in malting and mashing, but all kinds of grain sueh as oats, maize, buckwheat, riee, wheat, and rye, may be similarly treated. It is said that barley malt gives a better flavour than any other. It is therefore generally chosen when cheapness is not the first eonsideration. The distiller, for better class spirits, usually mixes malt and unmalted grain together, when in mashing the diastase of the malt changes the stareh of the unmalted grain into sugar, as before explained, and this is then fermented by the aetion of yeast.

Scotch or Irish Whisky is eommonly made from a mixture of malt, oats, rye, and barley, the

malt being about an eighth of the whole. The grain is coarsely ground and put into the mash-tun, hundreds of bushels at a time. Water is added at about 160°, the heat being kept up by hot-water pipes running round the mash-tun. Vigorous stirring by machinery is continued for some hours, when the grain is allowed to settle, and the greater part of the liquor (sweet wort) is drawn off. Hot water is again supplied and the stirring process repeated. This produces a weaker wort, but the conversion of starch into sugar still continues, and a third quantity of wort is frequently taken before the grain has given up all the sugar it is capable of forming.

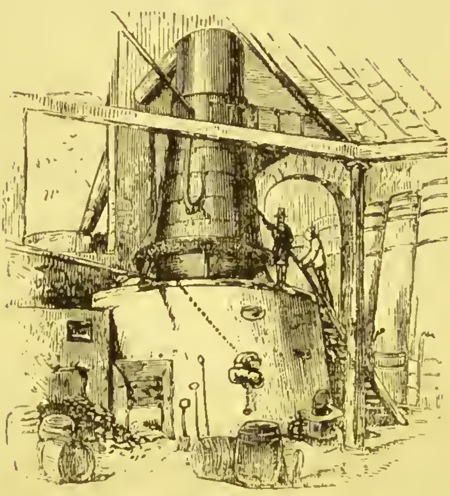

Fig. 40.—Wash Still.
w. Worm.

Fermentation is induced by yeast, as in beermaking, and is continued until all the sugar, or as nearly all as possible, has disappeared, when the fermentation ceases, the liquid becomes clearer and is known henceforward as "wash." If the wort has been strong, each 100 gallons of wash will contain as much as 12 gallons of alcohol.

The distillery has in it an immense still (fig. 40) called the wash still. To this the wash is transferred, and the operation we now understand brings over into the receiver water and alcohol with some flavouring matters in small amount, amongst which is found a highly destructive kind of alcohol,* known as fusel oil. This result of the first distillation is called in the trade "*low wines.*" A second smaller still receives the *low wines*, and by a second distillation the excessive water is partly or wholly removed, and the fusel oil somewhat lessened in amount, but a third passage through the still, if necessary, will complete the operation so far as the distiller usually carries it. The unfinished spirit now passes into the hands of the rectifier, whose business it is to separate excess of fusel oil, reducing it to what is considered a safe limit, to bring the

* There are many kinds of alcohol, but the one found in greatest amount in intoxicating drinks is meant when the word is used in common conversation. This, to distinguish it, is called by the chemist ethylic alcohol, because it consists of ethyl, with one atom of hydrogen, and one of oxygen. Another alcohol, named amylic alcohol by the chemist, because it consists of amyl, with hydrogen and oxygen as before, is commonly called fusel oil, and is a worse enemy to the body than ethylic alcohol, injuring the nerves and brain to a greater degree. This fusel oil is found in very small quantity in most distilled spirits, but it is present in a highly dangerous amount when the cheaper substances, mentioned hereafter, are used for obtaining sugar for fermentation, or when rectification is badly carried out. Its removal is a matter of considerable difficulty, and is accomplished, more or less completely, by repeated distillation, aided by filtration through animal charcoal.

spirit to an exact degree of strength, and to add sugar, colouring, and such flavourings as the taste of the public may require.

The foregoing methods give spirits of the best kind, but the cheaper sorts have a different origin, for the sources from which alcohol may be indirectly obtained are not exhausted. Potato, starch, and beetroot sugar are too often employed and yield alcohols of the most destructive quality, because they contain so much fusel oil. Weak sulphuric acid (p. 110) will give sugar from starch, but strong sulphuric acid aided by heat will give it from old rags, paper, woody fibre, &c., by first changing these substances into a gum which in turn becomes sugar. So spirits,* by fermentation of the produced sugar, "may be made from old rags and waste pawnbrokers' tickets"! There is something terribly sad and yet comical in the thought of the old toper swallowing his once dirty pawn-ticket as gin or whisky, but this is actually possible.

When spirits are distilled from sugar derived from such undesirable sources as those just now mentioned, the flavouring matters are absent, the spirit fortunately or unfortunately telling no tale of its origin, and so it is usually known as *silent spirit.* From such, taken from one still at one operation, may be produced gin, brandy, whisky, or rum. For gin, Juniper berries form the general flavouring, and it is too common, instead of using grain to take the highly injurious

* Food, Professor Church, p. 33.

silent spirit in a weak form and add to it the chosen flavourings, Juniper berries, aromatic seeds, and possibly turpentine, and distil once again.

British brandy, too, often originates in potato spirit, that is spirit made from changed potato starch, and is then coloured with burnt sugar and flavoured with a chemically prepared liquid, called green oil of Cognac.

The cheaper whiskies are made from silent spirit by adding a small amount of sugar, a fraction of colouring, and lastly creasote, to give the smoky flavour.

Rum, if genuine, is distilled from fermented molasses, but the chemist leads the rectifier, so that he gets over all difficulties of flavour, and silent spirit quickly becomes "Jamaica rum," or something sufficiently near it, to satisfy those whose craving by indulgence has become irresistible.

No one pretends that any of the spirits are food. They are almost exclusively alcohol and water, to which in most cases a small amount of sugar is added. They are occasionally grossly adulterated—gin, *e.g.*, which has been over watered, being made fiery with capsicum, but beyond manufacturing them from objectionable materials, and so getting fusel oil as well as ethylic alcohol, the chief trade trick is watering.

The strength of these spirits is indicated by the expressions "above proof" and "under proof" which require explanation. It is exceedingly

difficult to entirely separate alcohol from water. When this has been done, the result is called *absolute* alcohol—49¼ by weight of absolute alcohol and 50¾ of water make 100 by weight of proof spirit. If the alcohol exceeds or falls short of this amount, the liquor is said to be over proof or under proof by so many degrees. The common

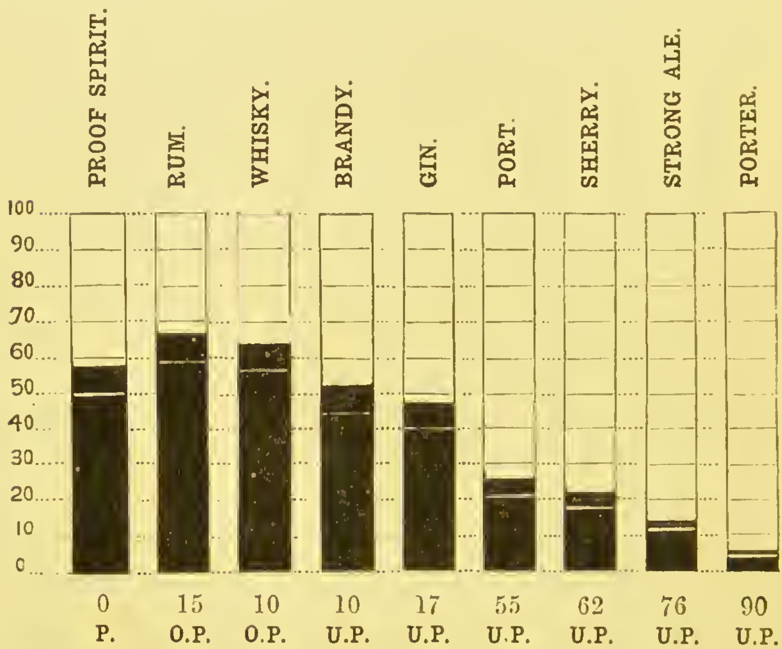

FIG. 41.

strength as sent out by the manufacturers is of gin about 17 under proof, brandy 10 under proof, whisky 10 over proof, rum 15 over proof.

The strengths are indicated by fig. 41. Where alcohol and water alone are taken into account, the other matters in spirits being too small for representation. In comparison with

these one or two wines and ales are indicated, the dark parts representing the alcohol by measure, while the white band shows the height to which the alcohol would extend if weights were being considered, alcohol being lighter than water. It is now settled by law that gin must not be sold weaker than 35 under proof, and other spirits 25 under proof. The publican therefore nearly always "breaks down" with water to the allowed limit.

The amount of good corn consumed in this horrible trade is appalling. In the last section of our book, figures will be given, but here it is sufficient to say that in one of the great London distilleries the wash still is a huge iron chamber holding 30,000 gallons, beneath which runs a furnace; that the worm from it descends, twisting its way through a vessel 30 feet deep, and that the spirit is at length stored in great vats, of which fig. 42 will give you a notion.

Fig. 42.—Spirit Vats.

The intoxicating liquors, of which a sketch has now been given, make thousands of homes a desolation. Pandemonium reigns where they

are sold, the health as well as the character of tens of thousands are being ruined by them, and they are costing a sum which presently we shall find we fail to realise, however much we may strive with the difficulty.

There is a matter that may make some of you uneasy unless an explanation be given. You know that our bread is fermented, and that yeast is put into it for the purpose. You may say, then, our bread must be alcoholic. This chapter gives the answer to this difficulty. The yeast does produce alcohol and carbonic acid gas in the bread. The carbonic acid gas blows up the dough as it forms, and so makes the bread lighter. It is in consequence better fitted for masticating or chewing, and so more digestible. The alcohol formed in the dough, however, goes off in vapour as the bread heats in the oven, and is raised far above 172 degrees, at which, you remember, alcohol boils. The bread thus loses *all* its alcohol, the steam from the oven carrying it off. About fifty years ago a company was formed in London to bake bread, and by condensation save the alcohol, which was to be sold as brandy, but they never got brandy enough to pay for the trouble caused, and so the company came to an end.

Our next task will be to consider the structure of our body, and the influence of these intoxicants upon it.

Section III.

ALCOHOL AND THE BODY.

CHAPTER XIII.

Alcohol and Digestion.

It is now evident to us that ales, beers, and wines contain little besides alcohol and water, and that spirits are practically nothing else. It follows from this that in studying the influence of intoxicating drinks upon the body, it will in most cases be sufficient to discover the effect of alcohol itself, always supposing it to be mixed or diluted with water, for alcohol alone no one could drink, and a very small quantity of it taken into the mouth would produce most alarming results.

The subject before us will require our earnest attention, for these bodies of ours are very complicated, and we certainly cannot well tell what it is best to choose and wise to avoid, even in matters of eating and drinking, unless we know something of their structure and the manner in which food is converted to our use. As we progress we shall not only be learning how to

fulfil the duty to ourselves and others, of preserving the health both of body and mind, but we shall get great delight from noticing the beautiful manner in which we are organised, of which David saw enough ages ago to make him exclaim that "we are fearfully and wonderfully made."

In early life our bodies while in health are continually growing* in every direction and in every part, and during our first twenty years they usually increase in weight about twenty times. This general increase of course depends upon our being able to make food into our very substance.

Large as is this increase, it alone, only represents a small part of the food taken into the body during the years of growth, for while the little child is becoming a man, and adding perhaps 120 lbs. to his weight, the food he consumes would probably weigh 15,000 lbs., as much as the flesh of six oxen, or a drove of between fifty and sixty sheep, and a railway-van full of bread.

We shall see presently that the greater part of the food, even when we are young and growing, does not go to increase our size but to make up loss, the wear and tear, as we may call it, that is going on without ceasing during life. Every movement or set of movements, whether conscious,† such as walking or singing, or uncon-

* Unimportant exceptions, such as the diminution of the thymus gland, are advisedly unnoticed.

† Known or felt by us.

scious, such as the beating of the heart, the flowing of the blood through the blood vessels, or the movements of the stomach while digesting the food, uses up some material which at first the food supplied; and this is even true of every thought and every feeling, so that all changes, whether in brain, or nerve, or muscle, or in the tiny parts we call cells, of which we, like the potato (page 58), are largely made up, require power or force to obtain which there must be loss of substance which the food must supply. This explains the need of food not only while we are growing, but during the whole of life, and why the body shrinks and becomes constantly lighter if food is withheld.

When we come to examine the losses the body makes we find they are of three kinds—water, solid substance, and heat or force—and it is quite clear at once that that which can repair the body must be able to make good one, at least, of these losses.

Some forms of these losses are not quite obvious, thus we can easily prove two ways in which we lose water that might without a little care escape detection. If on a cold day the hand is spread out flat on the window-pane, the water, which is always slowly escaping from the skin, will be deposited as a dew upon the glass around the fingers. Again, the air which is taken in, in breathing, is changed when it leaves the mouth in several ways, and amongst these it contains much more water. In the winter, we see our

breath and the breath of the horses given out as a cloud of steam, while the air going in is quite clear.

We now ask can alcohol make good this water waste? It is evident that the direct, natural way of accomplishing this, is by taking water either as a part of our food or as a drink. And as the loss of water is constant, we require considerable quantities, varying a good deal with the season of the year and the circumstances under which we are living. In hot climates people eat very juicy (watery) fruits; we, in the summer, eat such as lettuces, which are more than nine-tenths water, and we drink more freely. Alcohol is a material distinct from water, the two having in many respects quite opposite properties. It could not therefore be taken to make up water waste, even if it were not a brain and nerve poison.

Neither can alcohol replace the solid substance of the body. At one time it was considered that it formed fat, but this has now been shown to be quite incorrect in spite of appearances to the contrary, as will be fully explained in a later chapter. The different parts of the body such as brain, nerve, muscle, bone, cartilage, &c., all contain nitrogen, and so require for their repair nitrogenous or tissue-forming foods. They cannot for chemical reasons be formed out of alcohol, whose composition is C_2H_6O. It would be as possible to make a gold watch without gold, or a brick house without bricks, as to make up

parts containing nitrogen from a substance in which it does not exist. So far then alcohol is not a food, it can neither replace water nor solid substance. Neither does it increase the heat nor the energy (the force) of the body, but the main argument relating to this latter point must for the present be left.

The processes by which the food is so changed that it becomes at last woven as it were into our frame now require attention. They may be expressed in a few words, thus—(1) the food is dissolved or digested; (2) the fluid nourishment so obtained is carried into the blood, which by its circulation distributes the nourishment to every part; (3) each part takes out of the blood what is required for its growth and repair. These processes, all of which are hindered by alcohol, must be separately studied, beginning with digestion.

If a piece of bread be placed in water it softens but refuses to melt or dissolve as salt or sugar would, because it consists principally of two bodies, starch* and gluten. The former, consist-

* These can be separated as follow:—Take a handful of wheaten flour from which bread is made, moisten it so as to form a dough, and sew it up in a calico bag. Continually knead in the hands for an hour or more in a deep vessel full of water, or in a stream flowing from the tap. The starch will pass out of the bag and settle, while the gluten remains within. When the bag is opened, the gluten, a stringy, jelly-like body, of brown colour, may, on account of its insolubility, be gathered and pressed into more solid form, while still being washed with water. When made into a lump it can be pulled out into threads like

ing of carbon, hydrogen, and oxygen, is a heat and force giver, and the latter, containing nitrogen, is a flesh or tissue former. Neither of these is soluble, yet, during digestion, the bread is so changed that almost the whole of it is made liquid, the alteration beginning in the mouth, saliva or spittle being the cause.

While we are chewing, saliva is secreted from three pairs of glands, one pair in the cheeks (the parotid), one pair under the lower jaw (the sub-maxillary), and one pair under the tongue (the sublingual). The last-named glands can be easily seen by standing before a looking-glass opening the mouth and raising the tongue. They project somewhat, are rather light in colour and have a blue vein of large size running over

half-dried glue. It quickly putrifies, but may be kept for years as a specimen, in water to which a little white carbolic acid has been added. It can also be kept in alcohol, but this soon quite destroys its elasticity, making it extremely hard.

The presence of starch may be shown as follows:—Make a strong solution of iodine by adding as much iodine as will dissolve in solution of iodide of potassium, or purchase tincture of iodine of the chemist. Add twenty drops of either to half a tumbler of water. The brown fluid obtained will at once discover starch by changing it to a dense purple (iodide of starch). Wood or chalk or printing paper will remain unchanged if dipped in, proving that they contain no starch. Writing-paper, the shirt wrist-band, &c., will stain purple; while crumb of bread will be instantly almost blackened because starch forms seven-eighths of it. Similarly, rice pudding, boiled potato, sago, arrow-root, will be stained. Carrot, turnip, jelly, and custard, will remain uncoloured, as the first two contain only minute quantities of starch while the last two are free from it.

them. The blood travels through every part of these glands in thousands of small tubes (blood vessels) and gives out the material of the saliva to the cells. Although they are not all quite alike, a description of the parotid gland will give a good idea of the others. In this, the cells are collected into little bundles (*cc*, fig. 43). From each of these bundles runs a tiny pipe carrying the saliva into larger channels which by uniting form the duct (*d*). The whole of the ducts join and form the opening which lies in the cheek opposite the double teeth.

FIG. 43.—SMALL PORTION OF PAROTID GLAND.
cc. Cell Bundles, or Acini; *d*. Duct,

The saliva, during mastication or chewing, mingles with the food, and, should it be dry, by moistening it, fits it for swallowing, but upon vegetable foods, it has another and most important action. It will be remembered that, in plants (page 59), starch is constantly being changed into sugar, the insoluble being made soluble, and that in sprouting seeds, there is present a body called diastase which performs this work. The diastase of malt, for example, accomplishing it during the process of mashing (page 99). Starch, before it can enter our blood, and be distributed

over our body, must undergo the same change in *us*—*i.e.*, it must pass into the liquid condition; our saliva, therefore, contains a substance, having the same powers as diastase, but called Ptyalin,* which begins to make the alteration as we chew. This alteration is really digestion, and is known as buccal, or mouth digestion.

That ptyalin has been provided for the very purpose just considered, is proved by babies having no ptyalin in their saliva, milk containing no substance requiring its action. The ptyalin begins to appear when they are two or three months old, and before this time, no starchy foods should be given to them. It is important, also, to remember that the saliva must be alkaline,† or the ptyalin cannot perform its duty. In certain unhealthy conditions the former becomes acid, then a substance called maltine, because it is made from malted grain, and which contains much diastase, is often given as a remedy because it produces that digestion of the starch which the saliva when acid cannot accomplish.

To show how alcohol hinders saliva in its work, the following instructive experiments should be tried. If we take two tablespoonfuls of quite warm paste made with arrowroot, corn-flour, or wheat-flour and sufficiently stiff to hold a spoon upright in it, and then,

* Pronounced Ty-al-in.

† Of the nature of an alkali—*i.e.*, the opposite of an acid. Soda, pearlash, and ammonia, are all alkalies.

bending down the head and extending the tongue, allow two or three drops of saliva to fall into the paste, it will, upon stirring, very quickly become quite fluid, because the starch will in part disappear, and a thin syrup will be produced by sugar taking its place. One part of ptyalin changes 2000 parts of starch, but the presence of alcohol tremendously reduces its power, as can be very easily proved by taking two similar quantities of paste and adding to one a little brandy or methylated spirit and dropping saliva into both as before, when, notwithstanding the addition of the liquid, the one containing the alcohol will not become fluid so quickly as, or to an equal extent with the other. The maltine mentioned above may be substituted for saliva for public experiment, and it has this advantage, that measured quantities can be used. No kind of indigestion is more afflicting than that resulting from inability to change starch into sugar; it may even cause serious inflammation of the stomach, and here we see alcohol as directly tending to produce it.

Alcohol can, by a very simple and interesting experiment, be shown to be as injurious to diastase as it is to ptyalin. Take three similar tumblers (fig. 44), and cut three pieces of thin wood roughly round and large enough to rest in the tumblers two inches or so from the rim, then bore any number of holes in each—a red-hot wire being best for the purpose. Each hole should be big enough to hold a barley or wheat

grain standing upright. Arrange the grains in position, embryo downwards (see fig. 20), in the holes made by the wire, and place rather more than sufficient water in A to reach the under face of the wood, so that it floats freely. To B supply water to which has been added a tea-spoonful of methylated spirit or alcohol, or two teaspoonfuls of brandy or gin; even beer may

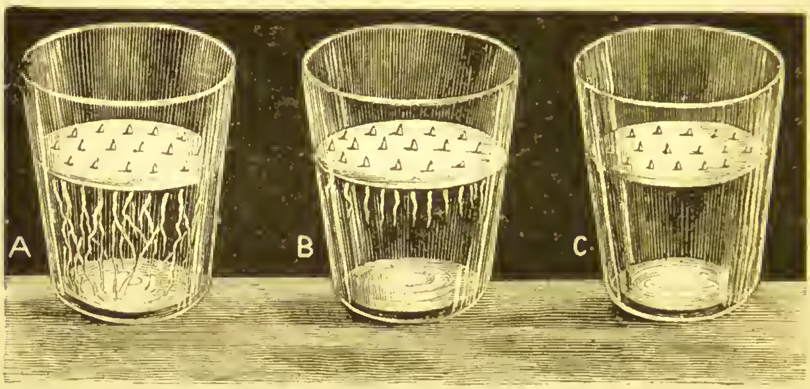

FIG. 44.

A. BARLEY GRAINS GROWING IN WATER;
B. DO. DO. WEAK ALCOHOL AND WATER;
C. DO. REFUSING TO GROW IN STRONGER ALCOHOL AND WATER.

be used, but of this a still larger quantity will be needed (see fig. 41). To C put three teaspoonfuls of alcohol or correspondingly larger quantities of the foregoing intoxicating drinks. Now cover down the tumblers with books or saucers, and place them in a dark cupboard. In a few (twelve or fourteen) days,* the roots in A will be long like those of a growing hyacinth bulb, in B they will

* In cold weather, the growth will be much slower.

be short and weak, in C they will not have grown at all, and possibly, if these grains in C be now changed to pure water, the roots will refuse to make their appearance. The alcohol has done more than injure the diastase, it has by a process of pickling killed the grains.

Before closing this chapter, let us note the necessity for carefully chewing starchy foods. There is a common idea that meat requires the greatest attention in this matter, but the animals may well teach the contrary, the carnivora* having no true molar or chewing teeth, while they swallow their flesh food in great lumps. The dog may be taken as an example, for how amusingly he gulps down one piece of meat in order that he may be in good time for the next. Yet even *he* is much more painstaking with a biscuit. Turning to vegetable feeders we have a model chewer in the cow. Otherwise she could never digest the enormous amount of vegetable food necessary to produce the milk she yields. All foods should be carefully masticated, but especial care should be taken with those that are starchy. Neglect here will certainly lead to indigestion in later life, if not in youth. The main point, however, is this that the most perfect chewing, in the presence of alcohol, cannot be effective.

* Animals living on flesh.

CHAPTER XIV.

Stomach Digestion and Alcohol.

Food, after mastication, is conveyed backwards in the mouth, and passes over the upper end of the pipe (the windpipe), which lies in the front of the throat, and which we can easily feel by the fingers. This pipe carries the breath up and down between the mouth and the lungs, and is closed at the moment of swallowing by a kind of flap, called the epiglottis, its purpose being to prevent our food going "the wrong way." The food now enters the gullet or swallow, a long tube behind the windpipe, joining the stomach with the back of the mouth. The gullet by no means allows the food to fall through it downwards, but really grips it by two sets of muscles, and, by moving itself much as a woman moves a hem through which she is pushing a bodkin and tape, conducts the food or drink into the stomach. That it does not *fall* down can be traced by looking at a horse drinking, when the water is seen to be carried *up* in a rounded lump towards the stomach, which, in this case, is higher than the mouth.

Suppose the food just referred to to be the bread we have already considered. A part of its starch has been converted by the saliva into sugar; but now, although in the interior of the masses swallowed this change will continue, it will be arrested on their outsides by the presence of an acid, which, as stated in the last chapter, prevents the digestion of starch. This acid is called gastric or stomach juice, and is supplied by about 5,000,000 of wonderful little glands, each made up of numerous cells of various kinds, and having various duties. The glands, which are embedded in the sides of the stomach, resemble in form a little tree-branch having three or four short twigs, the twigs stretching up their tiny length into the stomach from minute hollows or pits in the middle of which they stand.

Should the stomach have previously been empty, at the entrance of food, blood begins to flow in larger quantity through the multitude of blood-vessels which also lie in the sides of the stomach, and which are arranged around each gland like a little net, much as the cordage surrounds a balloon. The wonderful delicacy of these smallest blood-vessels can hardly be imagined, two or three hundred of them made into a bundle would only together equal the thickness of one hair. The blood rapidly travelling through these is the source whence the gastric juice is produced, and this now trickling down the sides of the stomach quickly covers the substances requir-

ing digestion, for until such are present no gastric juice is secreted.

The office of gastric juice is to alter and bring into solution nitrogenous matters, known by the general name of flesh-formers or proteids. It, therefore, in the case supposed, begins to dissolve the gluten, which is the nitrogenous part of the bread. To aid the process, the stomach, without our consciousness, continually rolls about, mixing and churning the food which has been put into it, just as we may mix up a nearly fluid mass in a basin by slowly twisting the latter in the hand. Meanwhile the food cannot escape, for the stomach is closed at both extremities, as shown in fig. 45. Whatever flesh-former is dissolved the result is much of the same character; for such bodies as the lean of meat, the white of egg, cheese, gelatin, gluten, and some others are made up of exactly the same chemical substances. So that whatever is said in reference to the gluten of bread applies with equal force to every other flesh-former.

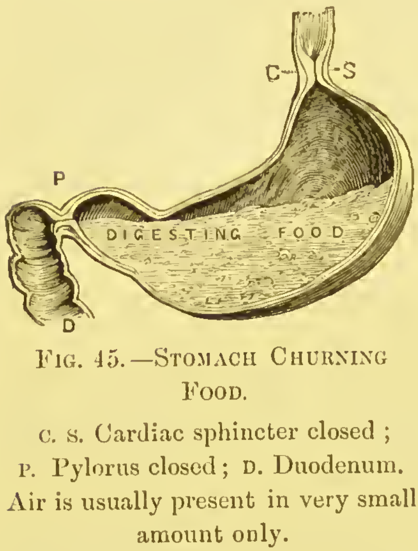

FIG. 45.—STOMACH CHURNING FOOD.

C. S. Cardiac sphincter closed; P. Pylorus closed; D. Duodenum. Air is usually present in very small amount only.

During the process of digestion, two things occur that we must endeavour to remember;

fresh quantities of gastric juice are continually being given out to continue the process, for a certain quantity of it can only digest a fixed quantity of food, and, next, as food substances are being made actually fluid they are picked up by the multitudes of tiny blood-vessels already mentioned, and carried away into the general blood current.

When the food as a whole has been brought to a gruelly consistency, it is allowed to pass on by the pylorus (gate-keeper) (figs. 45 and 47), which up to this point remains firmly closed. Digestion is still very incomplete, starches are only but imperfectly transformed, and fats have to be dealt with, but these matters do not now concern us, as our subject is stomach digestion, which, like that of the mouth, is greatly hindered by the presence of alcohol, as we shall now see.

In the year 1822, a very curious gun accident occurred to a Canadian named Alexis St. Martin. The shot tore away a portion of his stomach, making an opening, the sides of which healed without quite closing it, so that Dr. Beaumont, whose servant he became, could look into the stomach and note some of the remarkable changes going on during the time of digestion. As Alexis drank he could see the fluid enter the stomach. Did the stomach ache, he could search for the cause by the eye; and in the same way he could trace the bad effects of errors in eating and drinking. During eight years Dr. Beaumont carried on a

course of experiments and observations, made possible by this singular case; and, although he was no teetotaller, he has given us most valuable evidence of the constantly injurious effect of alcoholic drinks upon the stomach.

He inserted through the wound, which was fully as large as a shilling, small hollow silver balls, each having a side opening, through which had been passed, into the interior of the ball, certain quantities of beef, mutton, or chicken, &c., and it was always found that the time required for digestion was considerably increased when alcohol was present. This fact is due to three causes — 1st, The nitrogenous food is hardened and its soluble parts precipitated; * 2nd, the gastric juice is damaged in quality; 3rd, the glands themselves are inflamed and their cells injured. We shall have to consider these separately.

1st. *Alcohol hardens nitrogenous food.*—All know full well that in every museum alcohol, or spirits of wine, is used to preserve from change animal and vegetable substances, such as specimens of curious or rare fish (fig. 46), lizards, snakes, or fruits, and diseased formations, such as tumours, &c. We equally know that food is transferred to the stomach not that it may be preserved, but that it may as easily and rapidly as possible be so altered that it may give up its nutriment for the service of the body, and this common-sense

* So altered, that that which has been dissolved comes out of the dissolved state, generally falling to the bottom.

view is enough to condemn alcohol as an article of diet.

Alcohol preserves from decay because it kills all germs (Chapter VII.) that would cause putrefaction—a point that does not apply to digestion—but, besides, it deprives the substance to be preserved of water. It also coagulates or precipitates the soluble parts, altering the fluid condition into a more or less leathery one. A piece of tender steak shrivels quickly, and hardens under the action of alcohol,* soon becoming as tough as raw carrot, and, if it be carefully kept in strong alcohol, it will become so hard that thin shavings can be taken off of it with a plane, as from a piece of wood. These effects take place in the living stomach in a greater or lesser degree, according to the amount of alcohol mixed with the food, thus, of course, increasing the effort required for digestion, and so not only hindering work, but causing a loss of power to the body. For it is evident that the value of

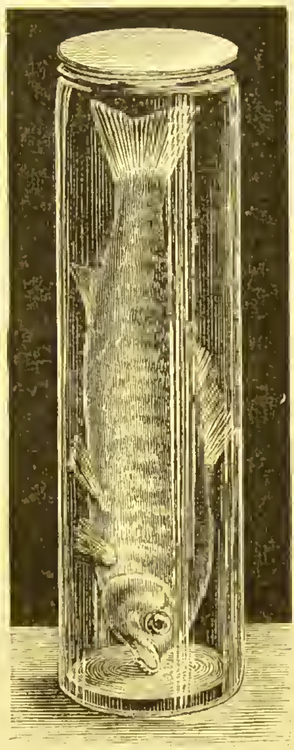

FIG. 46.—SPECIMEN IN ALCOHOL.

* Thin sections of animal substances are generally obtained for microscopic examination by first hardening with alcohol.

food much depends upon the readiness with which it can be digested, just as a sovereign in a man's hand is worth more to him than a similar sovereign which he can only obtain by going a journey for it.

The time occupied in healthy digestion will vary between one and five hours, depending on the kind of food; but in the presence of alcoholic drinks these periods may be increased four or five times, and yet the duties of the stomach be very far from complete, even when the food is at last allowed to pass the pylorus (P, fig. 45).

Besides the hardening of the actual food, fresh draughts of alcoholic liquor tend to reverse the work of digestion when it has been accomplished upon nitrogenous substances. These have become what are called peptones, which are perfectly dissolved in the water present, and ready therefore to go into the blood, but alcohol will, according to the amount taken, throw them out of solution, or as we have said, precipitate them. Dr. W. B. Carpenter, in his large work on physiology, puts this very clearly thus: "It may be safely affirmed that alcohol cannot answer any of those important purposes for which the use of water is required in the system, and that on the other hand it tends to antagonise many of those purposes by its power of precipitating most of the organic compounds whose solution in water is essential to their appropriation by the living body." Alcohol precipitates peptones and albumen in common with a great

number of other poisons, as may be easily shown thus. If we pour white of egg (albumen) into four glasses and add in order alcohol, nitric acid, solution of corrosive sublimate, and lastly carbolic acid, all will precipitate the albumen and cause flocking—*i.e.*, all these poisons tend to bring the albumen into a condition in which it cannot enter the blood.

2nd. *The gastric juice is damaged in quality.*—The gastric juice contains, besides a strong acid, a singular substance called pepsin, which is essential to digestion; this, like the ptyalin of the saliva is precipitated by alcohol, and so for the time being, prevented from doing its work—really, where large quantities of spirits or fiery wines are taken, digestion could not go on at all, but for the fact that the alcohol is rapidly drawn off by the blood-vessels of the walls of the stomach, thus leaving the pepsin to be redissolved and start afresh. All this can be proved by experiment outside the body. Artificial digestion can be brought about by adding pepsin* and a small quantity of acid to shreds of meat, and keeping the whole at about the temperature of the stomach (100° Fahr.), when solution is accomplished in three or four hours, if alcohol be not present. Similarly, Dr. Beaumont produced a half-artificial, half-natural digestion

* Pepsin is generally obtained from the stomach of a pig, which, while fasting, has had food kept in its sight. This has made the peptic glands active, and when the animal is killed, pepsin can be obtained in quantity.

by drawing gastric juice from the stomach of St. Martin, and with it digesting meat in a three-ounce bottle. In all these cases the addition of only very small quantities of alcohol delays the process, while a larger but still small amount stops it altogether. The reason of the complete stoppage being that the alcohol is not removed during the course of the experiment as it would be in the living stomach.

3rd. *The glands themselves are inflamed and injured.*—Alcohol is an irritant. If it be placed pure on the comparatively coarse skin of the hand it causes some inflammation, and the part is reddened;—what then must be its effect even if diluted with water, when brought into contact with the extremely delicate lining and glands of the stomach? The secreting cells of which have nothing whatever but their own walls to protect them. The damage caused was a matter of direct observation, in the case of Alexis St. Martin, and is known by every student who has seen the stomach of a deceased drinker.

Quantities of ale that would be regarded as extremely moderate, produce redness of the coats of the stomach, both in consequence of irritation and a nerve weakening (see Chapter XIX.); but much more marked effects quickly follow greater indulgence, especially if distilled spirits be the chosen liquors. Then the stomach becomes inflamed in patches, and a slimy matter is given off if hard drinking be indulged in for a few hours only. Further excesses lead to the most terrible

conditions, in which ulcers appear, and pus, mixed with dark clotted blood, exudes—a state in which it is impossible that the function of digestion can be performed, except in the most imperfect manner, so that the body not only suffers directly from the narcotic and depressing action of the poison, but is also weakened and distressed from the actual loss of nutrition. If the constitution has not been too seriously damaged, cutting off the cause of the mischief will usually be followed by rapid recovery, but perseverance in excess necessarily continues to increase and aggravate the mischief until, it may be, the final and indirectly fatal effects of alcohol upon the stomach are produced. In this hideous condition the delicate coating and pinkish glands which once lined the stomach have undergone complete destruction, and the preponderating colour is now a blackish red, while the broken-down surface is sloughing off offensive matter. Life under such conditions can hardly be continued, and delirium tremens or drunkard's madness then not uncommonly brings about a fatal termination. In this self-inflicted ailment mental agonies are added to physical suffering, for the maniac imagines himself pursued by hissing serpents, fiery demons, and every form that is capable of inspiring a frenzy of terror, and as he endeavours to flee from the enemies created by the fevered imagination of an ill-used brain, his screams and cries reveal the unutterable anguish under which he

suffers. It is singular that this last stage of alcoholic disease of the stomach is so regularly associated with what would appear to be a brain affection, but the nerves, as we shall see in a later chapter, really bring all parts of the body into relation with one another. With these facts before us, there can be no wonder that doctors recognise intoxicating drinks as the most frequent cause of that common ailment, indigestion.

Since one of the bad effects of alcohol is due to the way in which it abstracts water from living cells, it follows that the more it is diluted with water the less harm it will do, so that weak alcoholic drinks like table ale do far less mischief than strong wines and spirits ; and, again, if these be taken when the stomach is full of food they get greatly weakened by the fluids present, and by the gastric juice secreted. Therefore alcoholic drinks do most injury to the coats of the stomach if they be taken between meals or when the stomach is empty.

Before further tracing the action of alcohol it is well that we should summarise what we have already seen, which may be expressed thus :—

ALCOHOL		hinders or stops,
1 Injures diastase,	and therefore	germination of seeds.
2 Injures ptyalin,		digestion of starch.
3 Hardens food stuffs,		digestion of proteids.
4 Precipitates peptones,		digestion of proteids.
5 Precipitates pepsin,		digestion of proteids.
6 Injures gastric glands,		digestion of proteids.

CHAPTER XV

Biliary and Pancreatic Digestion and Alcohol.

It now remains for us to complete our study of digestion in relation to alcohol, and two points need to be specially remembered. First, it is but a small part of the starch which is actually changed in the mouth, and that the process is arrested, or at best only imperfectly carried on in the stomach, and that not by the gastric juice, but by the saliva mingled with the starch before swallowing, so that even after the most careful chewing, some starch remains unconverted into sugar when the stomach digestion is finished. Second, fats still have to be dealt with, for about these nothing yet has been said. The fat of meat so-called is only in part fat. The fat which, when separated, is called dripping is contained in cells; and these, again, are bound together by membranous parts of nitrogenous character, called connective tissue. These nitrogenous parts are digested in the stomach, so that the fat masses break up, but the fat proper remains unaffected until a later stage.

After the altered food has left the stomach it

passes into a pipe-like chamber, or sort of second stomach, called the duodenum (fig. 47). It is in reality the commencement of the bowel where digestion of nitrogenous matters is made more complete, and the remaining starch and fats operated upon. Two very large glands (fig. 47), called the pancreas or sweetbread, and

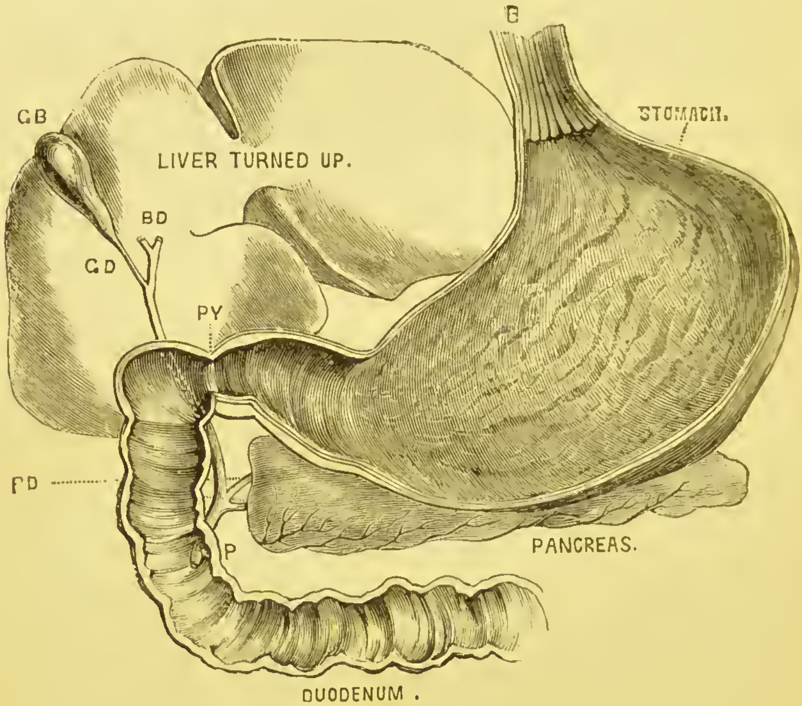

Fig. 47.—Organs of Digestion.

BD. Biliary Ducts from Liver; GB. Gall Bladder; GD. Gall Duct; PD. Pancreatic Duct; P. Papilla; PY. Pylorus; E. Entrance of Œsophagus into stomach.

the liver (the latter in a full-grown man weighing 4 lbs.) pour their secretions by the ducts PD and BD, into the duodenum, where they

terminate in a little tubular papilla or prominence, P.

The pancreatic juice possesses the curious power of digesting all kinds of food,—starches, nitrogenous substances, and fats—and so can beautifully carry on the work on whatever may have escaped the action of the saliva and gastric juice. The liver supplies bile, a curious pale brownish-yellow, and extremely bitter liquid, called gall in the ox, and which, when not immediately required, is stored in the gall bladder GB (fig. 47). The bile especially aids the pancreatic juice in acting on fats, breaking them up into myriads of globules, so very minute that they remain suspended in the watery mass as the butter globules are suspended in milk (fig. 48), and giving to the whole a cloudy milk-like appearance. They, on account of their minuteness, can pass into the tiny thread-like bodies (villi), which line the inside of the bowel, and pick up all remaining fluid nourishment, so that it may be carried into the blood. The villi differ somewhat in form in various parts of the bowel, but the greater number stand up

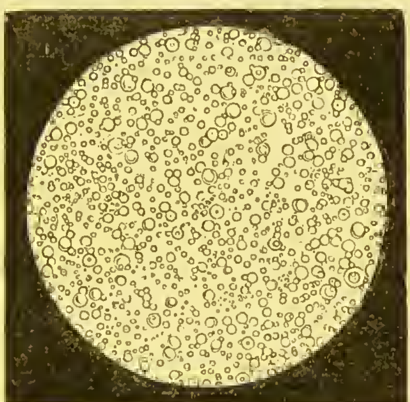

FIG. 48.—THIN LAYER OF MILK MAGNIFIED, SHOWING BUTTER GLOBULES.

from the surface like the threads (pile) of velvet, each one being from the thirtieth to the fortieth of an inch long, while between six and ten thousand are planted upon every square inch of surface. Their structure is extremely beautiful, their outside cells take the form of a finger of a glove. A, fig. 49, within which lie B, and then C, placed separately in the illustration for the sake of clearness. Into the finger on the one side runs up an artery (B *a*) carrying blood, the artery gives off numerous minute branches,

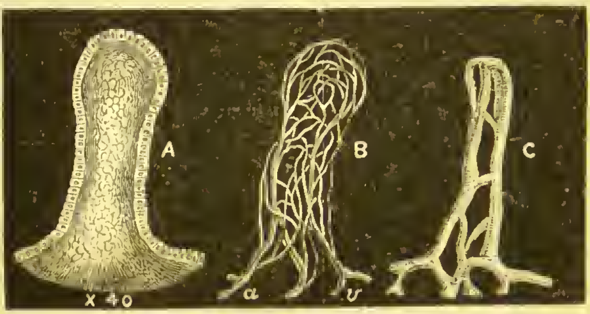

FIG. 49.—VILLUS OF BOWEL.

A. External Cells or Epithelium ; B. Blood Vessels which lie within A. *a*. Artery ; *v*. Vein ; C. Lacteal which lies within B.

which join together as a vein (*v*) on the opposite side, and by this vein the blood returns into the coat of the bowel. In the centre is a tube or tubes (the lacteal) having no opening, and through the sides of which the nourishment passes. The upper end of the lacteal has extremely delicate coats, which are muscular in character. The tube gathers in material and becomes widely distended ; it then contracts

and drives the nourishment forwards, and as the tubes are abundantly provided with valves, it cannot return. Each villus in this much resembles a pump. The nourishment gathered by all the two millions or thereabouts of villi is collected into a common receptacle, and then passes up a tube (the left thoracic duct) lying in front of the backbone behind the lungs. This tube enters a vein in the left side of the neck, just under the collarbone, and here the nutriment the food is capable of providing runs into the current of the living blood, becomes incorporated with it, and adds to its amount.

We have now to trace the action of alcohol on this stage of digestion, as we have already done in reference to the stomach, and in this our task is partly accomplished, for all that has been said applies. Alcohol, as we might judge, injures the pancreas, and hinders the work of its secretion. Its influence over the liver, however, is very special, and for this reason : Alcohol needs no digestion ; it is already liquid, and so soon as it is taken into the stomach, it is absorbed by the blood-vessels of the latter, and carried along a vein (*portal vein*) directly to the liver, which thus receives, as it were, the first blow from the poison, and so terribly does it suffer in consequence, that we find people, who are much exposed to the temptation of drinking, extremely liable to fatal liver diseases. Amongst an equal number of each trade, 2 nurserymen, 3 printers, 4 drapers, 11 brewers, and 27 publicans die of

liver disease, and it is not too much to say that not a drunkard could be found with a liver in a healthy state, so sad and severe is the effect of alcohol upon this organ. The importance of the liver is so very great that when it is disordered the whole body is more or less deranged. It picks up all excess of sugary matter in the blood, and packs it away in an insoluble form called *glycogen* until it is required by the system to produce either heat or force, and it renews the blood by removing from it waste and highly injurious matters formed during the general wear and tear of the body. From these it produces bile, and so economises by turning waste products to a good use.

When examined by the microscope, it is found to be composed of millions of cells, small tubes, and vessels, the latter forming a wonderous network which would extend many hundreds of miles could they all be put into a straight line. Alcohol, as in the stomach, so in the liver, irritates and inflames, and if its work be continued, at last destroys. Almost its first effect is to change the bile secretion from its natural yellowish colour to a greenish or blackish hue, and from a thin fluid to a thick one, the consistency of tar. The most common effect of alcohol is to kill numbers of the liver cells, and harden them so that the whole organ swells and becomes solid in texture and pale in colour. In hard drinkers, especially of spirits, another curious condition is often brought about. Fibrous mem-

branes are formed within the liver, and these, by contracting, draw in the outer skin like the buttons on the stuffing of an easy chair or sofa, until it is dented deeply in lines, leaving small parts sticking up, which have been compared to the hob-nails on the sole of a boot, and such a liver is, in consequence, called a hob-nail or gin-drinker's liver (cirrhosis). There are other forms of liver disease caused by intemperance, but those given are sufficient for our purpose. It is now clear that an organ of such size, delicacy, and importance cannot day by day be exposed to the action of a poison without seriously injuring it, and through it working mischief in the whole animal frame.

If, then, alcohol really delays digestion, and disorders the whole digestive apparatus, as we have already proved that it does, and alcoholic drinking is the great cause of indigestion, why do people so often believe that alcohol is a helper when it hinders? The wise man said: "Wine is a mocker, and whosoever is deceived thereby is not wise," and most remarkably does wine deceive with regard to digestion; for, in these cases, the feelings of the sufferer are not, as a rule, any guide to his general condition. Alcoholic liquors may have caused extensive injury in the stomach, and yet the drinker thinks that he is in fair health. Dr. Beaumont wrote, as follows, of St. Martin, in the account of his observations:—

"1st *August*, 8 o'clock.—St. Martin has been

drinking ardent spirits freely for eight or ten days. Complains of no pain, nor shows symptoms of any general indisposition. Examined stomach; inner membrane morbid,* considerable inflammation, and some ulcerous patches on the exposed surface, secretions vitiated. Extracted about an ounce of gastric juice, not pure and clear, as in health, quite viscid.†

"*2nd August*, 8 o'clock.—Appearances similar to those of yesterday morning. St. Martin complains of no pain.

"*3rd August*, 7 o'clock.—'From the surface of some ulcerous patches in the stomach, thick, clotty blood is exuding,'" and so on, day by day, until the effects of the drinking bout passed off.

Dr. Beaumont's experience is the same as that of medical men generally; usually, the injury to the stomach itself does not make the patient aware of it, and so he thinks none is produced.

In addition, alcohol deceives by making it appear that it is *necessary* to digestion. When the stomach is empty, but little blood flows through the blood vessels in its sides, as remarked in the last chapter, but when the food enters, the stomach's sides become pinkish-red, just as the cheek reddens in blushing, and for a similar reason—viz., an increased flow of blood, which, in a healthy stomach, the mere contact of food produces at once. From the blood, gastric juice secretes, and begins to trickle down the inside of the stomach, so that digestion is soon in full

* Diseased. † Thick.

progress. Alcohol is an irritant, and when added to the food, it does tend to excite the stomach, and so increase the amount of gastric juice given out. Carefully note, however, that the apparent advantage soon passes away, for the naturally delicate, sensitive stomach, having to endure the fiery liquor, begins to harden itself against its attacks, and, before long, will give up no more gastric juice, with the presence of alcohol, than it did at first to the more gentle excitement of the food. This hardening to suit the conditions under which the drinker puts his stomach, is called a "tolerance"; it is nature's movement in self-defence, and may be illustrated in many ways—*e.g.*, the delicate lining of the nose just covers a very sensitive nerve, which gives us the sense of smell, and if pungent, biting snuff be taken for the first time, it causes violent sneezing, while it injures both the membrane and the nerve. They harden themselves, however, as the doses are repeated, and by degrees, no sneezing follows snuff-taking, but then the delicacy of the sense of smell is gone—the nose has put on a tolerance.

Again, if a man gets his living as a clerk, his hands will be soft, for his work does not much wear his skin. Should he now suddenly take to rowing, his hands will blister and become sore, but the more the skin is worn the faster it grows, and if he continues his rowing, the skin will thicken, so that no hard work will cause blistering. The hands suit themselves to the conditions they are required to meet—they put on a tolerance.

When people begin to abstain, who have injured their digestion by the habit of taking intoxicating drinks with their food, they feel discomfort, because their poor stomachs have been made so sluggish, by the induced tolerance, that food alone is not enough to excite the proper secretion of gastric juice without the accustomed whipping. Unfortunately, while they are suffering from the diseased condition that alcohol has caused, they easily persuade themselves that abstinence does not suit them, and giving up they will actually say that they tried teetotalism, but it was a failure in their case, for they really found they could not digest their food without a stimulant. Poor deceived ones, if they will only persevere, their stomachs will soon become sensitive as at first, just like the hands of the rower, which will become soft if he gives up heavy work; and not only their stomachs, but their health, in every direction will be benefited.

While these sufferers are starting as total abstainers, to begin, perhaps, a happier, a better, a more hopeful life, we can help them by simply giving hot water to drink. The hot water will cause innocent excitement, gastric juice will be secreted, digestion will go on, and a cure from the ravages of the alcohol will be effected.*

But there is yet another way in which alcohol frequently deceives. As we have already learned,

* A hot weak infusion of cloves, to which lemon juice and sugar have been added, would be found useful in such cases if mere hot water is thought to be *distasteful.*

when the food is first introduced into the stomach, the pylorus (figs. 45 and 47), consisting of a great number of muscular bands, grasps the small extremity of the stomach and quite closes it. As digestion progresses, and the hard parts of the food soften and dissolve, the pylorus loosens its grip to allow the more liquid parts to escape. Should the stomach long contain masses which it cannot break up or digest, pain would be felt, and the sufferer would say he had indigestion. Taking brandy or some other intoxicating drink would, in this case, *appear* to do something towards a cure, for soon after the disagreeable symptoms would lessen, or would, for the time, pass away. A little attention will, however, show that the brandy instead of working a cure really has reduced the power of the stomach, and so made future attacks of indigestion the more likely.

We must first notice that the stomach has supplied to it nerves of sensation or feeling which most usefully let us know something of its condition. We are told by these when the stomach is in need and when it is satisfied, and if we eat to excess, the stomach through these same nerves aches, and so at once chides us for the past and warns us for the future. Alcohol is a narcotic, a destroyer of nerve power of every kind, and so the brandy lulls off these friendly nerves and stills their warning voice, and as the pain is reduced the taker of the draught thinks he is better. Secondly, the brandy not only lulls the

nerves of feeling, but it sends the nerves of the pylorus to sleep, or more correctly it narcotises them. Its muscular bands derive all their power to contract from the nerves which are supplied to them, and these nerves, stunned or, as we may truly say, paralysed by alcohol, let the fibres stretch out like a dead worm, so that food in all stages, whether digested or not, can pass on. What would be thought of a learner who conquered the difficulties of an arithmetic book by cutting out the leaves containing stiff questions? but it is after some such fashion that brandy gets the reputation of curing indigestion.

CHAPTER XVI.

Alcohol and the Blood.

When digestion is complete, and the liquified nourishment transferred to the blood, we have only made *preparation* for the feeding of the body. The blood, by its circulation, must accomplish this, by coming as the food store into contact with every part. It must—*e.g.*, visit the root of each hair, or the latter cannot grow; it must find its way throughout the length and breadth of every muscle, or the muscle must starve; and even be distributed through the bones, or they must decay; for, in a word, every tissue of the body, and every secretion also, is derived from the blood.

But the distribution of nourishment is only one of its offices, it is equally important for it to carry oxygen, because without it, neither heat can be produced, nor strength of any kind exerted, for just as the lighted candle (Chapter II.), continues to burn, because it unites with that gas without interruption, so we, during life, are constantly slowly burning or oxidising throughout the length and breadth of the body. The

blood, furthermore, acts as the general purifier, removing the waste and worn-out material, resulting from oxidation, which would otherwise quickly accumulate, clog, and even poison, the whole frame.

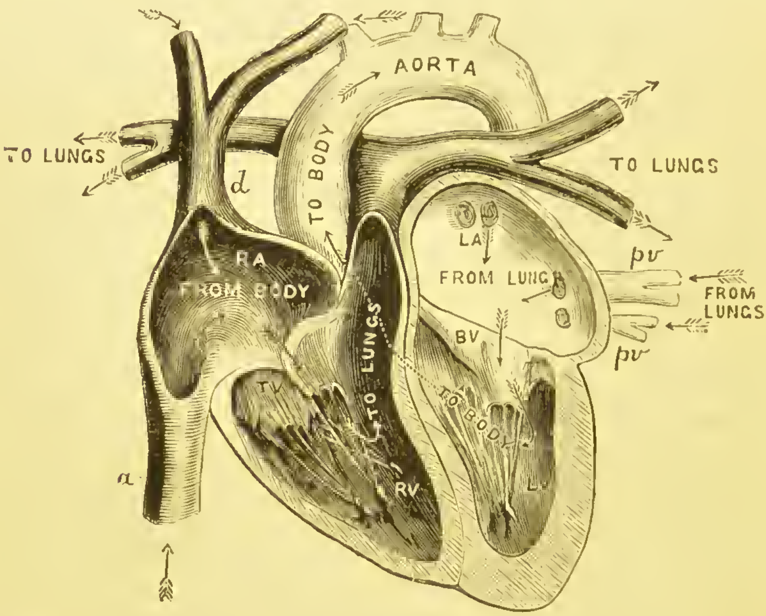

FIG. 50.—HEART IN SECTION—PART CARRYING DARK BLOOD DEEPLY SHADED; ARROWS MARK COURSE OF BLOOD.

RA. Right Auricle.	BV. Bicuspid or Mitral Valve.
RV. Right Ventricle.	*a.* and *d.* Ascending and Descending Vena Cava.
LA. Left Auricle.	*pv.* Pulmonary Veins.
LV. Left Ventricle.	
TV. Tricuspid Valve.	

The circulation depends on the heart, that, by ceaseless beating, is ever driving the blood over the body. Fig. 50 is a simplified view of its section, showing its four chambers—an auricle

and ventricle on the right, and the same on the left. Strong walls of flesh or muscle, particularly thick on the left side, surround the ventricles, which, by contracting, drive the blood onwards, until it returns to the point whence it started. The left ventricle (LV., fig. 50), no sooner fills with blood received from the auricle above, than it sharply draws its sides together, giving the beat which we can feel by applying the hand to the chest. The blood thus squeezed out cannot return to the auricle, because pressure on the lower side of the valve (BV.) closes it. The blood, therefore, escapes up the aorta, the largest and strongest artery of the body.

The aorta as it travels on, gives off smaller tubes, which are mostly destined to carry blood to muscles or to special parts, such as the brain, the liver, or stomach. These smaller tubes divide again and again, getting thinner and thinner, and more numerous until, at last, they spray off into most delicate, hair-like tubes, far too small to be seen by the naked eye (the capillaries, fig. 51), which afterwards unite and form veins. The spaces between the capillaries are, in general, exceedingly small. So close are these tubes in the flesh of the finger, that a

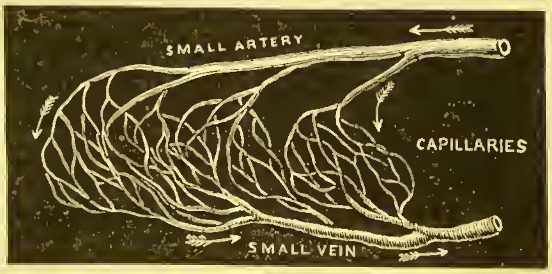

FIG. 51.—UNION OF ARTERY AND VEIN.

prick from the finest needle breaks a number of them, otherwise there would be no bleeding, for unless we are diseased, or have had an accident, all our blood is in vessels; and these, including the capillaries, are necessarily so inconceivably numerous in order that all our tissues may be duly provided, and the work of cleansing properly accomplished, that a man of average weight carries about with him a total of not less than 14,000 miles of them. The interchange of material between the blood and the tissues, by which the latter receive their food, and their oxygen, and have their waste matters removed, takes place through the sides of the capillaries, water playing a very important part in it; all substances that pass being at the time in solution, from which we at once see that the tendency of alcohol to precipitate or coagulate renders it, whenever it is present, a great impediment to the work of the blood, reducing nutrition and the power of self-repair, upon which our vigour, elasticity, and energy so much depend. During the time of growth, when cells multiply very rapidly and the nutrition of the tissues is very active, alcohol is particularly damaging, tending to stop development and growth. This fact has been taken advantage of by dog fanciers, as puppies that are desired not to increase in size have gin given to them.

Although then we feed at intervals, taking meals three or four times a-day, yet by the blood the body as a whole is ever being fed or nourished.

Those who are now studying this matter have the brain busy thinking, and so material in the brain is being rapidly used up (page 133), yet the brain is not being reduced in amount, for the thinking causes an increased flow of blood, and so furnishes an increased supply of new matter to make up what has been worn out by effort. The blood by this is reduced in richness, but the brain is not suffering, while, as food is digested, the loss to the blood is made up as we have already seen.

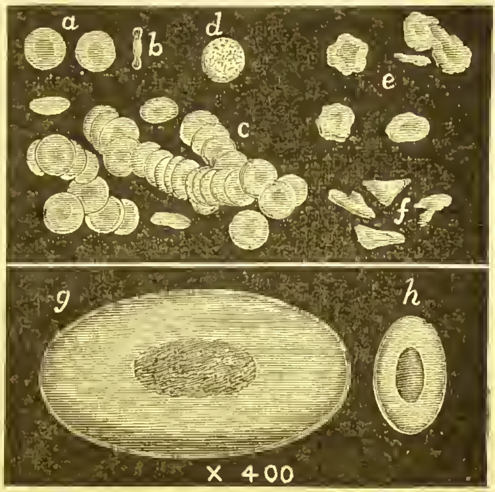

Fig. 52.—Blood Corpuscles Magnified.

a. Human Blood Corpuscles; *b.* Human Blood Corpuscle, Edge View; *c.* Human Blood Corpuscles, partly adherent; *d.* Human White Corpuscle; *e.* Human Blood Corpuscles Injured by Alcohol; *f.* Human Blood Corpuscle Destroyed by Alcohol; *g.* Corpuscle of Salamander; *h.* Corpuscle of Frog.

A change in colour takes place in the capillaries, which must be considered before we further trace the course which the blood follows. The colour of the blood depends upon the presence of a countless multitude of tiny jelly-like bodies, called corpuscles, which are diffused in a colourless fluid (the plasma), very much as the butter glo-

bules (fig. 48) are diffused through milk. These corpuscles, although wonderfully small, constitute rather more than one-third of the whole of the blood, for their number is beyond our imagination. They are each in shape like a flattish round biscuit (*a* and *b*, fig. 52), and if a hole be made carefully in a sheet of paper with a pin, the hole, $\frac{1}{32}$ inch in diameter, would be about ten thousand times the size of one of their flat faces. Three thousand, two hundred of them put down edge to edge, touching each other, would reach an inch, and ten thousand would in a similar way be required to surround a half-penny; yet an average child of six years has a multitude in its blood great enough to twice completely encompass the globe at the equator. There are in addition colourless bodies known as white corpuscles (*d*, fig. 52), but their number is relatively small, healthy blood usually containing 14,000 red corpuscles to each white one. Both are undoubtedly damaged by alcohol, but it is principally to the red corpuscles that our attention must be directed.

The corpuscles, and not the fluid part of the blood, are the oxygen carriers. When fully charged with oxygen, their colour in mass is a bright scarlet, imparting to the blood its redness; but as they pass through the capillaries they give up more or less of their oxygen, mainly in producing heat or force as required, and then the red colour gives place to a darker one, until at last the blood becomes purplish black. The plasma

at the same time gathers up the waste products, carbonic acid gas, consisting of carbon and oxygen CO_2, always being one of these. The blood now not only weakened and deprived of oxygen, but loaded with carbonic acid, and other impurities, passes on from the capillaries to the smallest of the veins (fig. 51), which, by uniting, form larger ones in which, when near the surface, as at the inner side of the wrist, the dark colour of the blood may be seen through the semi-transparent skin and vein wall.

While passing through a vein in the left side of the neck, digested nutriment is poured into the returning blood from the thoracic duct (page 157), reproviding it with the material lost in feeding the tissues.

All the returning blood, gathered at last into two veins (*a.* and *d.*, fig. 50), is emptied into the right auricle of the heart (RA.). The auricle contracts, and the blood descends into the right ventricle through a wonderful valve (TV.), consisting of three hanging flaps of membrane, and is now forced out into the lungs, where it is again distributed into capillaries in order that it may renew its oxygen and discharge its carbonic acid gas by coming into contact with the air taken in as the breath.

As we breathe, air is carried down the windpipe, which soon divides into two to supply the right and left lung. By continual dividing and subdividing, an immense number of bronchial tubes are formed in the lung, each terminating

in a cavity or bag surrounded by little pouches of extremely thin membrane. Into all of these pouches the air at least penetrates. They are estimated at nearly 2000 millions in number, having the astounding total surface in the lung of a man, of over two thousand square feet. Around the air cells the capillary blood vessels are arranged like close nets, with such small meshes, that the openings between the capillaries are often smaller than the capillaries themselves, and their united surface must be at least as great as that of the air cells just given.

An enormous surface of blood is thus exposed to the action of the air in the air cells, for the air and the blood are only separated by membranes of almost unimaginable thinness—and the wonder becomes the greater as we reflect that the air by the breathing is continually being renewed, while the blood travelling on is changed in the capillaries many thousands of times every twenty-four hours. What a marvellous arrangement is this to provide abundant opportunity to the blood corpuscles to secure their oxygen, and to the blood plasma to give up its carbonic acid gas, for it is evident that the facility of the interchange exactly agrees with the amount of surface upon which the interchange can take place.

The blood now purified, and again scarlet, because recharged with oxygen, returns from the lungs by the pulmonary veins* (*pv.* fig. 50). It

* Called veins, because they bring blood to the heart; they carry arterial blood nevertheless.

has been strengthened, as explained above, and so is completely refitted for a new journey. It now enters the left auricle, to pass immediately the bicuspid valve (BV.) and fill the left ventricle, from which we commenced to trace its circuit; the whole course being performed probably in something less than half-a-minute. Experiment seems to prove this quite clearly, but some physiologists think the time about one and a-half minutes.

Next we must examine the effect of alcohol upon the blood, and its work, beginning with its action on the blood corpuscles, because we have now the key to the reason of their smallness and the peculiarity of their shape, in that they are flat. A little thinking will show that both result from nature's effort to secure surface. As we divide, surface grows. A stone broken in half has all the old surface with the addition of the new. Had the corpuscles been twice their present diameter, their united surface would have been one-half of what it is, and so on in proportion. Again, by making them flat (their thickness, only about one-sixth of their diameter, *b*, fig. 52), and not spherical, like butter globules, their surface is increased threefold. The corpuscles of a man of twelve stone, in full health, have the vast total surface of one acre, which is about 3000 times as great as that of his entire skin, and the whole of this is devoted to getting and giving oxygen. It is needless, in face of such surprising facts, to point out the

great importance of this gas as the minister of life in every part of the frame.

When we ask how alcohol influences such living machinery, beside which, for complication merely, the spinning-jenny, with its 10,000 bobbins, sinks into utter insignificance, we learn, as before, that that which nature has secured for our benefit with such beauty of contrivance and prodigality of means, alcohol thwarts. It deprives the corpuscles of part of their water and so shrinks their size, altering their outline, as seen at *e*, fig. 52, so that their total surface is lessened, but the worst mischief arises from reducing their vitality, by which their power to absorb oxygen is very greatly diminished. Dr. Harley has shown that if to one of two similar quantities of freshly drawn ox-blood a small quantity of alcohol be added, and that then both be agitated with a measured quantity of oxygen, the pure blood will absorb a far larger amount than that containing the alcohol. Similar experiments have been tried with the blood of various animals with the same result. On this account the blood of those addicted to drinking never becomes beautifully scarlet, but assumes only a reddish purple tone, which imparts its own peculiar colour to the countenances of those drinkers that spend much of their time in the open air, as in their case, for a reason given in a later chapter, the small blood vessels near the skin become permanently enlarged. From the same cause also the flesh of intemperate people when their bodies

are dissected is found to be of an unhealthy, dark colour; this, together with a peculiar pappiness from excess of water, is quite enough to indicate the unfortunate habit to which they have been addicted.

Although some of the oxygen used up in the tissues is converted into water by uniting with hydrogen, especially that of fats, it is principally, as already stated, converted by union with carbon into carbonic acid gas, which is in turn thrown out by the lungs. That CO_2 is thus thrown off is very easily demonstrated, for if the mouth be placed over a tumbler as in fig. 53 so as to close its opening almost perfectly, and then the breath, which has been held for a moment or two, be slowly thrown out till the chest is empty it will be found that a lighted taper as at (*a*) will be immediately extinguished, and the experiments given at fig. 14 may be repeated, except those of pouring, for in this case only about 5 per cent. of the oxygen has been displaced by CO_2, but this is quite enough to extinguish the taper. We may test for CO_2 by adding lime-water and

FIG. 53.—EXTINGUISHING TAPER BY AIR FROM THE LUNGS.

shaking, or we may vary the experiment by blowing through a glass tube into that liquid, when the CO_2 of the expired air will form chalk, as fully explained in Chapter IV.

When food is taken, the increased activity set up by feeding the tissues increases the amount of CO_2 given out, but when alcohol is consumed CO_2 is formed in less quantity because the tissues begin to suffer at once from oxygen starvation and probably also from the narcotic effect of the alcohol, and therefore the body becomes less capable of exertion or of heat formation. In the present state of our knowledge it is not possible to give the reason positively, but it is certain that for some cause the blood containing alcohol is not only less able to pick up oxygen in the lungs, but it is less able to deliver it up again to the tissues, so that diminished change goes on, and therefore vitality is reduced. This reduced vitality is also accompanied by reduced nutrition, for blood containing alcohol is less able to give up the food matters it is carrying for the benefit of the whole body, and therefore the more active parts such as the heart soon begin to suffer. See Chapter XX.

Burning into carbonic acid gas and water a certain amount of tallow will always produce precisely the same amount of heat or energy, whether we can measure it or not, and so burning by example, a certain weight of sugar in the body will produce, under all circumstances, precisely the same amount of heat or energy as the case may be.

(See Chapter V.) Take a lump of sugar, moisten it in a tumbler, and add slowly a strong solution of chromic acid. The chromic acid* gives up half its oxygen and converts the sugar into CO_2 and water, which liberates so much heat that the liquid may be kept boiling for some time. The amount of sugar oxidised exactly determines the amount of heat produced. This again, is precisely equal to that furnished within the body, when the blood corpuscles are the oxidisers. It then becomes manifest that heat can be produced and work accomplished in exact proportion to the power of the blood in affording oxygen, from which it follows, as a rule of three sum, that as the amount of alcohol increases the amount of possible work decreases.

The racer who has to do his very best, or fail, can have no greater enemy than alcohol. All his power comes from burning (oxidising) material by the action of his blood, and this action alcohol reduces, hence total abstainers are the best athletes.

* I have devised a form of the chromic acid experiment which is peculiarly striking, but which should not be attempted by those not at all accustomed to chemical manipulation. Make a hot saturated solution of potassic bichromate, to which add, in a porcelain vessel with caution, strong sulphuric acid stirring constantly until the chromic anhydride is precipitated. It is now, when cold and shaken, of the exact colour of arterial blood. Cork it as explained in footnote page 41. When added slowly to sugar, it yields half its oxygen and becomes, like the blood in the capillaries, dark blue. At the time of the alteration CO_2 is given off and heat is generated, so that all the vital changes are exactly imitated.

They win on the bicycle, they win as rowers, as runners, as walkers, as cricketers, because so called strong drink deprives of the source of strength, namely oxygen. Similarly those who take alcohol cannot bear a low temperature as well as others, the fur hunters of North America know by experience they dare not drink alcoholics while they have to face the Arctic snows, and we see at once why a teetotaller got nearest to the North Pole, and stood the cold better than the rest. When the blacksmith wishes to reduce the heat of his fire, he covers it from air by ashes. The effect of the ashes is like that of the alcohol on the blood. The blacksmith desiring a strong heat uses his bellows, so we, when we need to exert ourselves and do our best, begin at once to breathe more quickly, and to fill the chest more fully. If we run we take in five times as much oxygen as when sitting in a chair, the higher vitality needing more. But this boasted alcohol just tends to bring our blood to the condition of that of the reptile, in which because only half oxygenated, it is purple instead of red, and in which the corpuscles are 100 or more times as large as our own, see *g h*, fig. 52, because these creatures with their natural sluggishness have less need of oxygen. How utterly absurd is the idea that intoxicating drinks assist the hard worker in getting through his accustomed duties. Let him who desires to feel bounding life and mastering energy avoid the agent which though promising hilarity really saps the basis of all that is truly life.

CHAPTER XVII.

Alcohol and the Blood—*continued.*

Whilst we are in health, the temperature of the body—*i.e.*, of the head and trunk, is wonderfully uniform, and seems nearly independent of external conditions. If a thermometer (fig. 37) be placed under the tongue or under the arm-pit, it will rise almost exactly to 98·4°, a variation of 1°, more or less, being unusual. This temperature has, therefore, been called blood heat, and applies with insignificant changes to men of every climate. And curiously the variations are mostly the opposite of what we should expect, the blood of Icelanders being slightly warmer, and that of native Africans 2° cooler, than that of Englishmen.

Our limbs, unlike the trunk, vary in temperature considerably. When we feel uncomfortable from cold, and perhaps from this cause have our fingers or toes aching, the blood in the extremities may be down to 50° or even 40°, yet the test applied to the tongue, as before, will find very little change, ordinary blood heat being nearly if not exactly registered. When we are flushed with

violent exercise, or are oppressed with the heat of summer, the same is true. I have remained for thirty minutes together in a temperature of 258°, 46° hotter than boiling water, in which any kind of food would quickly cook, and yet the temperature under my tongue only rose 3°. This curious constancy of the body temperature indicates both that it is essential to health, and that there exists some very perfect system of self-regulation.

Important variations from the health standard not only always indicate disease but give some clue to its nature, hence the doctor commonly uses the thermometer under the tongue, as already explained, by which he gets a key to the character of the ailment, a fall in temperature accompanying many diseases, such as jaundice, asthma, and cholera, while a rise* indicates irritation, inflammation, and fever, the progress of the latter being better estimated by the thermometer, than by any other means. Alcohol, therefore, by lowering the temperature induces a condition akin to disease, and must interfere with the best discharge of the functions of the different organs. One example will suffice. Semi-artificial digestion, page 149, with human gastric juice, has been clearly proved to be most perfectly performed at 100°; and this is the temperature at which the stomach is maintained while in health. Any fall

* It is often difficult to distinguish cases of apoplexy from those of intoxication. The thermometer, however, provides a test, as temperature rises in apoplexy and falls in drunkenness.

below this will, therefore, reduce the activity of the digestive faculty.

The means of self-regulation, possessed by the body, now requires consideration.

Oxygen, we have fully seen, by uniting with material within us, is the source of heat. If we are fairly active, our clothing ample, or the air in which we live, warm, the oxidising of the material of the muscle in its exercise will perhaps furnish all the heat required, or even an excess of it. In the latter case more blood is caused to circulate in the skin. We all know the red flushed appearance of those that are over-heated. The skin now parts with heat rapidly by mere air contact, a matter more fully treated in Chapter XIX., but the main power of regulation lies with the perspiration, which is greatly increased in consequence of the greater blood flow, and the vapour thus produced carries off the heat that is superfluous. In the skin of the finger (fig. 54), the opening from the perspiratory glands can be readily seen with a magnifying glass. Each opening is the termination of a tube (PT., fig. 62) which ends beneath the skin in a coil forming the gland PG. The whole of the skin is provided with these sweat pores, although they are not

FIG. 54.—PORTION OF SKIN OF FINGER, SHOWING SWEAT PORES.

equally close in every part; their total number being about 3,000,000.

If we need to be convinced as to the cooling effect of evaporation, we need only pour a few drops of ether into the hand and then blow over it, when a feeling of intense cold will be produced. So in the apparently astonishing feats of remaining in an oven while a dinner is cooked. Rapid evaporation is the explanation. In my own case, to which I referred, I drank about two pints of cold water, and this by literally steaming from the body prevented mischief. By limiting oxidation, and by increasing perspiration, the body has extraordinary powers in preventing temperature rising excessively beyond the health standard.

If, on the other hand, the oxidation of the muscles and nerves, during their use, does not provide all the heat necessary, and under usual conditions, especially in cold climates, it would not, sugars, fats, &c., commonly called combustive foods, have to be oxidised in addition. The respiratory process, without our consciousness, acts as regulator by supplying increased quantities of oxygen; for we breathe more frequently and deeply as the surrounding air grows cooler and as the demands for heat production extend, until, as we see in Arctic climates, oxygen is carried by the blood in sufficient quantity to burn up the almost incredible quantities of oil, beside nitrogenous matters, which the Greenlander is capable of consuming every twenty-four hours.

Alcohol, besides wasting our heat by allowing its escape through the skin, as we shall have to study when dealing with the nerves, lessens our power of bearing cold, because it reduces the oxygen which respiration can carry into the body, and this exactly agrees with observed fact. When alcohol is first taken, it causes a slight increase of temperature from a weakening of the nerve system, which, we shall study, as just hinted, in its proper place, but very soon the thermometer under the tongue no longer rises to its 98·4, but sinks down and down until perhaps it is one and a-half or two degrees below the health standard, and there it may remain for some hours or even, in bad cases, a day or two, depending, of course, upon the amount of alcohol that has been imbibed, as well as upon the constitution, age, &c., of the drinker.

A very singular point now arises; since alcohol tends to depress temperature, when the body is surrounded by cooling influences, might it not be useful in assisting the body to bear very high temperatures. Here, again, the verdict is against alcohol, for resisting high temperatures is essentially a vital act; the greater the vigour of the constitution, and the more active the skin, the more successfully will the battle be fought, and since alcohol reduces vitality, it is on the side of the enemy. Those having to endure intense heat in iron foundries, glass houses, &c., know how alcoholic beverages cannot be indulged in

while work is in progress or the muscles become incapable of exertion. The stokers down in the hold of steamships passing through the Red Sea, are exposed to a most trying test, as the heat in which they work is terrific, and they know that alcoholic drinks would simply be destruction. They, therefore, commonly take oatmeal and water. It is even true that alcohol is far more mischievous in high than in low temperatures, for in the former the respiratory process is less active than in the latter, and as a consequence, the alcohol remains longer in the blood. It passes away more slowly in the expired air, and it is itself more tardily oxidised. Sir Charles Napier, in an address to the 96th Regiment at Calcutta, said, "Let me give you a bit of advice, don't drink. Let me tell you you have come to a country where, if you drink, you are dead men. Be sober and steady, and you 'll get on well; but if you drink, you 're done for." Sir Charles Napier knew the army in India well, and had seen the awful havoc drink had caused among the British soldiers there. He practised what he taught. He, with forty-four others, was once attacked beneath a burning sky by sunstroke, and he alone survived. He accounted for his remarkable escape thus, "I do not drink, that is the secret; the sun has no ally in the liquor amongst my brains."

It has been proved that the oxygen, absorbed by the corpuscles in respiration, becomes the means of expelling the CO_2 given up by the

plasma.* If then the corpuscles absorb less oxygen under the influence of alcohol, the plasma gives up less CO_2, and this will explain, in part at least, why alcohol promotes sluggishness,† dreaminess, and stupor. It is very probable that any increased quantity of CO_2, especially in the brain,‡ is the main reason for that sense of fatigue which usually comes on at night. Alcohol tends to produce this very condition, and none can have watched persons who habitually take intoxicants (especially those that contain sugar, such as ale) without noticing the drowsiness which usually follows indulgence. So true is this that many who have to exercise their minds in their business, dare not take beer, although willing, until the work of the day is over.

Alcohol, then, operates precisely like the very impure air of a crowded and ill-ventilated room, bringing on drowsiness and inability to act vigorously, or to think quickly and clearly, and for exactly the same reasons ; and it is here well worth remembering that the reduced vitality of old age is always accompanied by a diminished quantity of oxygen in the blood corpuscles, and a diminished volume of CO_2 in the expired air. Alcohol, therefore, among its other virtues, puts the young into the position of the old—not in wisdom, but in weakness.

* See Carpenter and Powell's " Physiology," page 260 ; or, Huxley's " Elementary Physiology," page 112.

† The part the nerves play in this will be found in Chapter XVIII.

‡ Carpenter and Powell's " Physiology," page 684.

The blood, under the action of alcohol, suffers a series of alterations besides those mentioned, one of the gravest being a reduction in its power of coagulating. When blood is drawn from the body, it forms in a very curious way a stringy gelatinous substance called "fibrin," which makes the blood half solid. If the finger be cut, blood escapes from the divided vessels, but the bleeding soon stops, because the escaped blood, by the aid of the fibrin coats over the wound, and allows the healing process to commence, the temporary cover in turn being reabsorbed as the cure progresses. Were it not for this coagulation, the most trifling injury would allow the blood continually to drain away until death might follow. Alcohol reduces both the quantity and the quality of fibrin produced by the blood escaping from a wound, and so increases the difficulty of cure. On this account savage nations without surgical arts, if unacquainted with intoxicating drinks, recover in a most remarkable and rapid manner from injuries that amongst drinking communities would be commonly fatal; but when they, through contact with white men, contract habits of intemperance, they lose their power of repair, and suffer even more seriously than civilised races.

Not only is the amount of fibrin in the blood of drinkers decreased, but the amount of water is increased, because, as we have already pointed out more than once, alcohol clings to water most firmly, and this adds another danger in the

case of wounds. The brewers' draymen are unfortunately illustrations, for as a class they drink immense quantities of ale or porter, and in consequence suffer often most severely from a trifling accident. A mere scratch, especially if on the leg, instead of closing and growing smaller, spreading into a sore which, in spite of medical treatment, will run on, until at last the whole frame is brought into a critical condition, from matter being carried over it by the blood which passes the wound, and if erysipelas sets in the poor fellows are quickly gone. The very changes last considered work mischief apart from accident, producing an unhealthy condition by allowing the more fluid parts of the blood to constantly escape through the sides of the blood vessels more freely than they should. This is often indicated in the skin of the face by pimples and blotches. The whole interior of the body lacks firmness, the blood vessels are liable to rupture, the power of resisting strain is reduced, and any small internal injury becomes serious because of the loss of self repair. Diseases of various kinds are readily induced, and the duration of life is shortened.

Alcohol, in part, escapes from the body unaltered, but it is certain that a portion is oxidised in the blood. If very small quantities are taken, by far the larger part is, without doubt, thus converted into CO_2 and water, yet it cannot properly be considered a heat-giving food, for, instead of sustaining the functions of the body

in health, it alters them and brings about conditions only consistent with disease, besides which its effect on temperature is the reverse of that of food proper.

An explanation is here required of a commonly observed fact, which might, if not understood, be thought to show that alcohol was a food. Many persons under the influence of intoxicating drinks, ale and beer especially, grow bulky and gain weight, while, on the other hand, many become lighter in the early days of their teetotalism. The increased weight is in large part an increase in water, which now forms more of the blood and more of the tissues. The greater bulk does not give greater strength, but rather adds to fatigue, as the water is simply a load to be carried.

Some of the before-mentioned bodily increase, however, is due to fat, which is produced as waste and accumulates for the following reason. The body perishes in the using, the brain is worn out by thinking, the muscles by working, and since something has been said in reference to the brain previously, let us now take the muscles for our explanation. The muscles are made up of enormous numbers of fibres, each one of which, like a garden worm, can contract (shorten) and become, while short, thick. The contraction and thickening of the fibres causes the same changes in the form of the whole muscle. As an illustration, the bending of the arm is brought about by the contraction of the biceps (fig. 59); but in the

contraction of the muscle, some of its substance is oxidised, decomposed, and removed, while fat, or that which is equal to it, results from the first step of the oxidation, so that it may be said that muscle when used is at first in certain of its fibres changed into fat. In healthy conditions the fat is now oxidised into carbonic acid and water, and removed by the blood, when new muscular fibres take the place of the old. If alcohol be, however, present, the amount of oxygen carried is reduced, and part of the diminished amount is demanded by the alcohol* itself for *its* oxidation, so that the fat cannot be oxidised and therefore remains. By degrees fat takes the place of muscular tissue, the muscle undergoing what is called fatty degeneration or fatty† decay.

* The oxidation of the alcohol, it is not denied, produces heat, but it is not on this account entitled to be classed as a food. Its action is not to sustain the functions of life, but to alter them, and its general effect is not to warm but to lower temperature. The metal arsenic would, if taken, oxidise into arsenious acid, and in so doing would, like alcohol, produce heat, but no one would be rash enough on that account to call it a food. It must be judged by its all-round qualities. They declare it to be a violent poison. In a similar way a large number of poisons may be shown capable of heat formation, but to class these as foods would be manifestly ridiculous, although they may as drugs be useful in unhealthy conditions.

† Fat tissue is necessary in certain amount. It is a store of heat-producing material waiting to be used up if required, but this healthy fat is absolutely distinct from the fat mentioned above, which takes the place of the working tissues of the body, and brings every organ it affects into a sadly diseased state. Fatty degeneration may exist in a frame thin and shrunken.

Alcoholic drinks tend, when even taken in very small quantity, to bring about this condition, and perhaps the reason why they shorten life is more traceable to this cause than any other. The heart loses force, the liver becomes flabby, pale, and inactive, the kidneys suffer in the same way. The blood-vessels grow weak, the brain and nerves soften, and indeed almost every part of the body sustains injury.

Even the blood itself from lack of oxygen may be said to suffer from the same disease, the fat in it increasing to four or five times the healthy standard, and it in consequence continually deposits fat particles in the tissues. From one or both of these two reasons the fat accumulates and the person grows in bulk, because he or she is simply carrying about dead, useless, worn-out material of the former self, a load and a burden, decreasing activity and comfort and strength. Waste fat and water are poor things of which to boast. They simply mean heaviness, flabbiness and slowness. Alcohol is in no true sense a food.

The following experiments illustrate the chemistry of the subject in relation to animal heat:—

Half fill a very small stoppered-bottle * ($\frac{1}{2}$ dr.) with bisulphide of carbon and drop into it 4 or 5 grains of phosphorus, which will at once dissolve, forming a fluid that requires neat handling, although it is not dangerous. It is best to keep the stoppered bottle in a screw-lid wooden box,

* A corked bottle must on no account be used.

such as chemists supply, lest by any accident the bottle should be broken.

Take three perfectly similar pieces of paper, crumple up two and place them on a slate, the third is laid on the mouth of a tumbler and slightly depressed in the middle. Now pour a few drops from the contents of the bottle upon each of the three, beginning with those crumpled, and covering one of the latter by an inverted

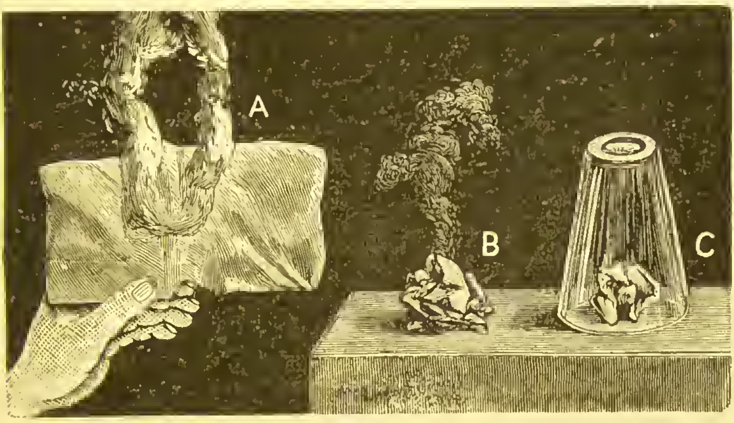

FIG. 55.—HEAT AND INFLAMMATION PRODUCED BY OXIDATION.

tumbler (B, fig. 55). Having returned the bottle as quickly as convenient to its case, lift the uncrumpled paper and hold it as at A, and drive air over it with the other hand, which is used after the manner of a fan, or gently blow at it with the mouth. The carbon bisulphide quickly evaporates and the phosphorus rapidly oxidises, forming heat, which in turn quickens the oxidation, until at last temperature rises sufficiently to induce inflammation. The crumpled piece, B, does not inflame

for a minute or so later, the delay being caused by the reduced surface and consequent diminished oxidation. The tumbler so completely checks oxidation that C refuses to inflame altogether until the tumbler is lifted, but ignition quickly follows its removal, even had the paper remained covered one or two hours. A may represent our condition during active exercise, B ditto of repose, and C the state brought about by alcoholic indulgence.

To demonstrate the presence of carbon in food, sulphuric acid, by abstracting water, is sufficient. An amusing illustration will make the general principle clear. Write or draw on paper with sulphuric acid and water. The lines are invisible until the paper is warmed over a lamp, when the acid separates the hydrogen and oxygen, and leaves the carbon behind, the lines immediately becoming intensely black. Pieces of bread treated as the paper will blacken for the same reason. The carbon in sugar is best shown by filling a tumbler with loaf-sugar, moistening it with a little hot water, and then pouring on sulphuric acid. The result is a mass of porous coal swelling up above the top of the glass, which might humorously be compared to a cauliflower head, although it is of the wrong colour. Warm honey, warm golden syrup or treacle may be substituted for the sugar, when a dense carbonaceous mass will in each case be produced. That from the last substance very closely resembles, both in character and the manner of its production, the

basis of more than one kind of blacking which has received public approval.

To show that the carbon of the food is given off in the CO_2 of the breath, take a test tube (A, fig. 56), fill it with CO_2. (It can be poured through a funnel (see B, fig. 14), if no better apparatus is at hand.) Drop in a small piece of clean sodium, and loosely cork, or add plug of cotton wool (fig. 22). Direct the flame of a spirit-lamp by a blow-pipe (*b.p.*, fig. 56) against the tube, so as to heat the sodium to redness. It instantly seizes the **O** of the CO_2, liberating the carbon before invisible, so that it forms a thick black deposit on the tube, as at B, while the soda formed by the combustion of the sodium solidifies higher up. This experiment as I have devised it is not difficult of performance, and is extremely striking.

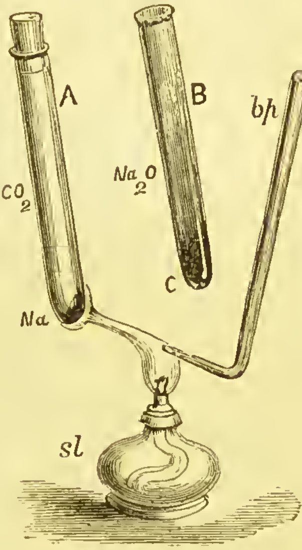

FIG. 56.
OBTAINING CARBON FROM CARBONIC ACID GAS.
s.l. Spirit-Lamp.
n.a. Sodium.
c. Carbon.
b.p. Blow-pipe.

CHAPTER XVIII.

Alcohol and the Brain and Muscles.

As we watch a company of children marching, the regularity of their movements delights us. Each left or right foot in the whole line strikes the ground at the same moment, and that in exact obedience to the word of command. At the order, "Left," every left leg moves forwards, and so on for every command given; but how is this to be explained, for we all know legs hear nothing, and can only move as we determine they shall. The reason is as follows:—The ear receives the sound, and then passes the impression on to the brain, which, after all, truly hears. No sooner is the order recognised, than the will of each child, acting also in the brain, causes the leg to move, and as the brains of all act alike, each foot comes to the ground with the beautiful uniformity, we just now noticed.

But what connection is there between the ear and the brain, and the brain and the legs? In what manner can one act on the other? We know that by wires of iron or copper, electricity is made to convey telegraphic messages from

place to place. In a somewhat similar way, information, messages, or orders travel to or from the brain, throughout the whole body, by means of delicate whitish threads, we call nerves (see fig. 57). By these the brain and all parts

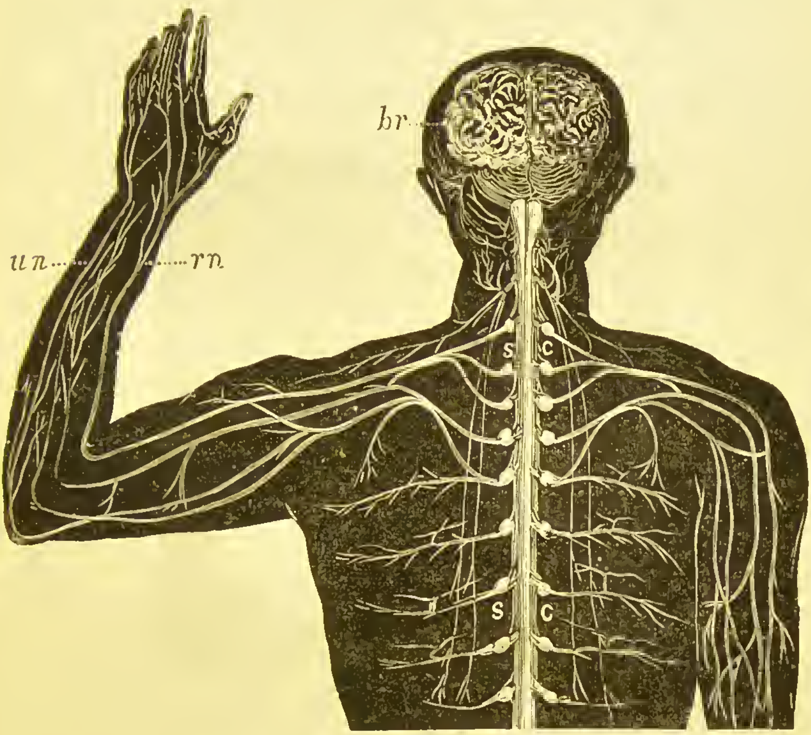

FIG. 57.—BACK VIEW OF BRAIN AND PART OF NERVE SYSTEM.
br. Brain ; *sc.* Spinal Cord ; *rn.* Radial Nerve ; *un.* Ulnar Nerve.

of the body can communicate with one another. Near to the brain (*br.*) and spinal cord (*sc.*) we find large nerves, or more properly nerve trunks, for they are in reality bundles, containing in some cases thousands of nerves, as can be under-

stood by the section of one of these trunks (fig. 58), in which are shown the cut ends of the numerous nerves lying closely side by side. These run along together, after the manner of telegraphic wires, which near to important stations, are often laid in bundles, yet at last each wire reaches its own proper destination, and so does each individual nerve, notwithstanding the multitude of them that the body contains. As

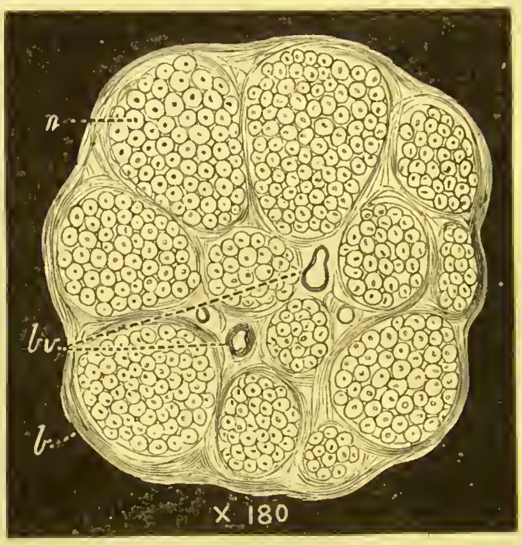

Fig. 58.—Section of Nerve Trunk.
b. Bundle ; *n.* Nerve ; *bv.* Blood Vessels.

the trunk travels on it continually grows smaller by paying off the nerves which are needed to bring the parts they visit into communication with the brain or spinal cord. These separated nerve ends eventually become in some cases so delicate that half-a-million of them could pass at one time through a pinhole.

Immediately the sound beats in the ear, the impression travels through a nerve * to the brain, from which a message by other nerves goes off to the leg. Let us now examine the first half of this process. If my little finger is pinched, the information runs along nerves up my arm to my shoulder, and joins the spinal cord (*sc.*), the largest† bundle of nerves running up my back, and thence on to my brain, and there the feeling of pinching is produced. But it is important to notice that the information takes its course through *un.*, the ulnar nerve, while if my thumb be the sufferer, the course would be through *rn.*, the radial nerve, which joins the spinal cord higher up, and sends its information to the brain by a different set of nerve threads. In this way I, through my brain, can distinguish the exact spot whence the information comes. The nerves, which thus carry impressions to the brain, are called nerves of sensation, and are distinct from those along which messages travel *from* the brain to the different parts.

To return to the marching. The order being received, the will, acting through the brain, sends a message down the spinal cord,‡ along

* The expression nerve is commonly used, but it is, of course, a nerve bundle or nerve trunk that is implied.

† The spinal cord is much more than conductive, but the idea given is sufficient for our purpose.

‡ The action of the nerve cells of the cord, in receiving and interpreting the impression into regular action, is here omitted for the sake of simplicity.

the nerves (nerves of motion), which finally reach the legs; and now some of the muscles of the leg, which are attached to the bones, contract exactly as they should, in order to put the limb into the position required.

To understand this better, let us look at the way in which we bend our arm at the elbow. There is situated in front of the bone (humerus) of the upper arm, a muscle biceps (*bi.*, fig. 59),

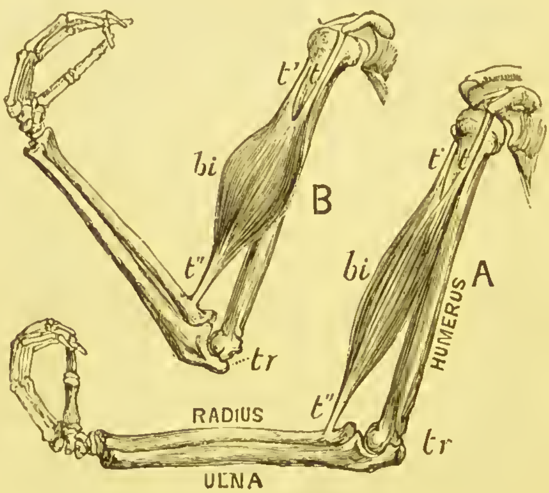

FIG. 59.—ARM SHOWING ACTION OF BICEPS MUSCLE.

bi. Biceps; *t*, *t'*, *t''*. Tendons of Biceps; *tr*. Point of Insertion for Triceps.

which is attached by two tendons (*t*, *t'*) to the shoulder, and by another tendon (*t''*) it is fixed at its lower end to one of the two bones of the lower arm, called the radius. When it is our wish to bend the arm, a nerve message (impulse) travels from the brain into the muscle named, when its fibres contract, making the whole shorter and

thicker, and so pulling up the radius and the ulna, which is bound to it, until the arm takes the position at B, where the altered form of the muscle is evident. There is another muscle which helps the biceps, but it is less powerful. Now we notice that it is not only necessary that the muscle should contract, but that it should contract the exact amount required, or the arm would not be placed precisely as the will had determined. Our power of exact control when in health is very remarkable. The shortening of the biceps by one inch when in the position A will raise the hand ten inches, into position B, and since we can easily adjust the hand to the one-tenth of an inch, it follows we must be able to regulate the length of the muscle to the one-hundredth of an inch.*

On the other side of the humerus bone another muscle is provided (the triceps) joined to the elbow at *tr.*, and this by contracting reverses the movement and straightens the arm. Whatever the change of position may be, it is evident that these two muscles must constantly give and take, one lengthening while the other shortens, and in bending and straightening our

* Some of the smaller muscles have to move with far greater accuracy. By example, singers of ordinary powers can adjust their vocal chords, by which the pitch of the note is regulated, to the $\frac{1}{1200}$th of an inch, and those of very delicate ear to the tenth part of this in sharpening or flattening a note, and that without any previous trial, and in using an organism hidden from sight, and which has little sensation.

arms as we should do, in such a simple matter as measuring a piece of calico, these two muscles constantly play at see-saw as it were, and move in most perfect obedience to our will and with the greatest nicety, or measuring would be impossible.

Think of our nerves directing and properly balancing the contractions of the numerous muscles required to put our fingers, arms, hands, and legs, into position for even ordinary play such as batting or catching at cricket, and we shall be filled with astonishment at the nicety of the work of the nervous system in merely moving our bodies which is only one portion of its duty. The quickness with which it operates is equally surprising; for as the ball is flying swiftly, our eyes follow it, our brain sees and judges what we ought to do, and through this nerve action our various muscles rapidly contract and lengthen, adjusting our movements to all the inequalities of the ground, so that our balance is preserved, and at the same time carrying us by our legs to the right spot. Similarly our arms, and all our fingers too, are properly bent, and without our thinking about the way it is done, the ball is in our grasp. This accuracy and quickness of nerve action is essential, if we are properly to perform the ordinary work of life. Far more do we need it if we are to excel in life's battle.

The importance of the brain is so great and its work so large, that although its weight ranges in adults between 2½ and 4 lbs., it has passing

through it one-fifth of the whole quantity of the blood, or about seven times as much as its average share. Alcohol, as a narcotic poison freely passing from the stomach into the blood, cannot therefore but exert a most disastrous influence over the brain, and over the whole nervous system;* small doses, though not producing much effect that is visible, still most certainly interfering with the delicacy, correctness, and quickness of the action of the nerves upon the muscles, and blunting the mind and the perceptions, while larger doses show their disastrous action in disordered movements and the rolling and tumbling—the common symptoms of intoxication.

We see then that muscular movements depend upon nerve power, and that as alcohol injures the nerve it impairs the muscle. Besides this, since all the senses of touch, sight, hearing, smelling, and tasting, depend on the nerves, it follows that alcohol injures them all, and so not only makes a man less a man, and less capable of enjoyment, and we may add less capable of pain by blunting every sense and weakening every muscle, but it makes him inaccurate, slow, and uncertain, for the nerve system ceases to be able to guide as it otherwise could. Here we have another set of reasons from those we reached in Chapter XVI., showing why

* Brain and nerve substances specially retain alcohol, because of the large quantity of water entering into their composition. Alcohol is in consequence specially destructive to them.

total abstainers are the finest and the strongest athletes, the best marksmen, the most successful travellers, the most enduring workers. In the teetotal army Captain Webb swam the English Channel, Weston walked down all opponents, Hanlan beat the world at rowing, Grace gives the highest average at cricket, and hundreds of others, celebrated where high-toned bodily powers are wanted, whom time would fail us were we to try to mention. Outside the teetotal army there is a big but motley crowd of jugglers, tumblers, gymnasts, and acrobats, who do most astounding tricks involving extraordinary accuracy, and who abstain not for the sake of others but for their own sakes, knowing full well that drink would make their hands forget their cunning and banish their cleverness. I have had conversation with many of these, and they all tell the same story, but two well-known examples will suffice.

Several years ago, I was giving science lectures in connection with the Royal Agricultural Society's Show in Carlisle, and here having a sort of official entry, I had the opportunity of seeing some extraordinary shooting. An assistant placed a grape upon his head, aim was taken by the performer at about twelve paces distance, and the grape was smashed by the bullet. An address card was borrowed, and the word "Mr." was shot out of it, as it was held up by the assistant before-mentioned. He now extended his fingers, and placed them in front of the card

which was held by the other hand. The pistol was brought to position; and I held my breath while three shots were fired, making three holes between, and without touching the fingers, although each shot must have passed within one-quarter inch of the skin. Similar, and if possible more terrible tricks were now performed, the shooter standing with his back to his assistant, and taking aim over his shoulder by looking into a looking-glass placed before him. The mutual confidence of the men was apparent, and I felt that their necessary steadiness of nerve and perfectly uniform condition, which must have been the basis of their confidence, could only be maintained by the practice of abstinence from the brain's worst enemy. After the exhibition, I put some questions to this most marvellous marksman. Having said, "Do intoxicating drinks influence your shooting?" this characteristic answer was given. "You don't think I take 'em, do yer? I don't either. I found out drinking was a game that wouldn't do for me long ago." The man was Ira Paine, the champion pistol shot of the world.

Another marksman now appeared, and the rifle was introduced, wonders being performed with it. I will only describe one trick as a sample. Twelve glass balls were thrown at once into the air by a spring, and by a repeating rifle the whole twelve were shattered before one had reached the ground. The eye had followed the twelve marks, and the gun had been pointed accurately, and discharged with incredible quickness, the explosions

being as rapid as one could count. Alcohol would not allow of this smartness, thought I. Some things about the shooter were not what I could approve, yet, I felt he certainly must abstain, for trifling indulgence would spoil the quickness of his vision, and reduce his extraordinary control of muscle. I ventured to ply my questions. The same story. "If I were to drink, I couldn't shoot," was the reply of Captain Carver, the champion rifle shot of America. What a lesson is this! God has given to us wonderful powers. There is hardly anything we cannot accomplish with patience and perseverance. To conquer difficulty is one of our very highest delights; and alcohol only snatches from us power of conquest, and reduces and weakens where it does not destroy.

It is not only true that alcohol from the smallest doses makes muscle uncertain, it makes it weaker, for alcohol reduces contractile power.* Experiments on the muscles of cold-blooded animals have shown this most clearly, and in addition, that the muscles cannot keep up their condition of contraction for so long a time as when free from this narcotic poison.

Nothing more, surely, need be said to cause

* Dr. Richardson weighted the hind leg of a frog, and by means of electricity stimulated the muscle so as to ascertain the utmost weight it could lift. Then, administering small doses of alcohol, he discovered that the muscle became more and more feeble, until at last its power was reduced by the narcotic to less than one-half of its power when uninfluenced by alcohol.

young people in their early-life freedom from the slavery that drink induces, to even shudder at the thought of being tempted by such an agent. It, at the very outset, hinders all true effort, and reduces all those powers of body and mind, in which we can rejoice as our birthright. To take any of it is to be a loser, and might it not perchance lead on to every excess and to cruelties and crimes, the very names of which should make us blush, for we must never forget that the great danger of alcohol, like that of all narcotics, is, that little induces a desire for more. It is thus and thus only, that every drunkard has been made. Those who begin to drink enter upon a downhill road, the slope of which may be at first but slight, yet it has a dip constantly growing sharper and sharper, and the travellers on it as they proceed, find it more and more difficult to check their pace, until perhaps they suddenly discover that they are on a declivity—starting into a run, the beginning of a headlong rush, which there is no power capable of stopping but the bottom of the abyss, where despair, disgrace, and death swallow up their victims.

We will now go forward in our study, following the action of alcohol, as more and more is taken, until at last all power is gone, and the man becomes as inert as a log.

The brain has general control, and presides as it were over our actions, but there exists distributed in the spinal cord,* a sort of secondary

* This is called the vesicular substance of the cord.

and inferior brain which has the power of sending orders, and performing mechanical acts apart from the brain itself. By example—as we walk, our brain is free to think and to observe, while the spinal cord, having received a sort of general order from the brain, does the work of moving the limbs. As alcohol impairs the action of the cord, the brain proper has to undertake part of its duty, and so movements become more and more difficult and laborious. As intoxication advances, the limbs cannot be perfectly straightened out. (The comic artist always draws a drunken man with his knees half bent), the lower lip begins to drop, and the eyelids begin to fall unless unusual effort is exerted. The gait gets more and more unsteady—for the power of making the muscles contract in mutual agreement is being rapidly lost—the tongue and organs of speech cannot longer do their duty, and so words are badly pronounced, and the voice grows husky, the mind becomes confused, the higher feelings die, silly boasting and needless anger show that judgment has grown weak, or is completely dethroned. In this condition, there is obtuseness of feeling, bruising or cutting cause but little pain, for the nerves of sensation like those of motion have lost their power.

In the next stage, the brain completely gives way, and the body sinks down as though dead, the awful condition known as dead drunkenness being reached, and now the foolish drinker having no longer the power to lift the intoxicating

cup, has a chance of recovery, for his heart, is still kept going by little nerve centres, inclosed within itself, and which are not yet so seriously interfered with as the nerve system generally, his lungs also continue to heave, for a reason of a like kind. These will supply the frame with blood and with air, while the hated poison is exhaled, excreted, and oxidised, until he is restored from his voluntary madness.

In closing this chapter, let us carefully note that an idea which some entertain, that a small dose of alcohol acts in one way, and a larger one in a totally different manner, has no foundation in truth. Alcohol begins by weakening nerves, and, therefore, weakening muscles; and the whole of its course, from the commencement of the very mildest excitement to that of the most complete stupefaction, is that of nerve derangement. We shall presently be able to trace that the excitement itself, is not due to any vital elevation, or increased vigour imparted by the alcohol, for as we have seen its action is of an opposite kind, but is attributable to two indirect influences; (1st), The loss of control over the circulation by which its reserve for the future is prodigally paid out in the present; and (2nd), The struggle of nature to expel the enemy. These questions will most particularly occupy us in the next two chapters.

CHAPTER XIX.

Alcohol and the Brain and Muscles—*Continued.*

We have as yet almost exclusively considered those movements that follow the will, called voluntary, but movements of another kind are constantly in progress. We cannot by the will make the heart stop or go more quickly. Our breathing, although partly under our control (for we can hold our breath a few seconds or breathe quickly as we choose), still usually proceeds without consciousness,* we being awake or asleep. In this same unconscious way our nerve system regulates the quantity of blood which shall visit any special part, so that the amount shall be suited to varying circumstances. One case of this kind we have already noticed — the increase in the amount of blood circulating in the coats of the stomach by the introduction of food so that the gastric juice needed for digestion may be provided (page 143).

As the heart propels the blood from the left

* These unconscious actions do not originate in the brain but in some other nerve centre, generally the spinal cord or the sympathetic system upon which space forbids our entering.

side with great force, the largest of the arteries need stout walls to sustain the pressure. They are in consequence encircled by strong elastic tissue, to which are added many layers of muscular fibres which, like india-rubber rings, grip them and give power of contraction as circumstances require. As the arteries by subdivision become smaller, their coats get thinner. The muscular fibres are first reduced to a single layer, then the fibres separate (*m.f.*, fig. 60) and finally disappear as the arteries reach the capillaries. These muscular fibres are abundantly provided with nerve cells

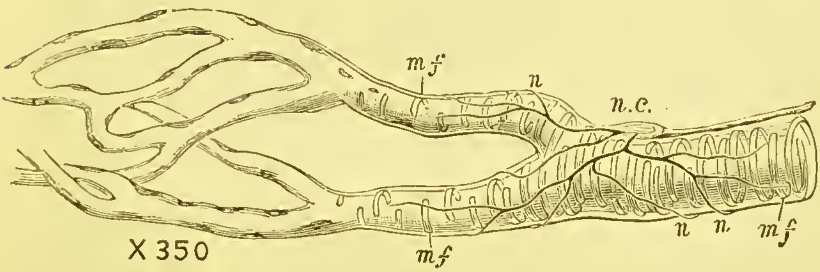

FIG. 60.—MINUTE ARTERY AND CAPILLARIES.
n.c. Nerve Cell; *n.n.* Minute Nerves; *m.f.* Muscular Fibres.

(*n.c.*) and minute nerves (*n.n.*), whose duty it is to keep them in such a condition of contraction that the small arteries may allow sufficient blood and no more to pass. These nerves (called vaso-motor), are often considerably affected by the feelings. Should we be suddenly frightened, a nerve impulse will contract completely the muscular bands of the small arteries of the face. The arteries being thus greatly reduced, the blood will be in large part stopped in its flow, and ghastly pallor, with a feeling of coldness, result.

The opposite effect is produced in blushing; here the nerve stimulus is withdrawn, and the muscular fibres losing their power to contract and grip the vessel, stretch, as we before said, like dead worms. The blood, driven in from the heart, then opens out the small arteries to their fullest extent, the delicate capillaries stretch under the growing pressure, more blood moves in the cheeks, and heat is felt, while the red fluid, showing through the skin, gives the passing pink tint we all so well know.

The deceiver alcohol is a master hand at producing blushes, for it makes the body blush all over, inside and out, by paralysing (making powerless) the nerves which, through the muscular fibres of the arteries, regulate the circulation. A little experiment will help us to grasp this. In the web of the frog's foot the microscope shows the circulation in a most marvellous way. The oval blood corpuscles are seen travelling through the arteries, breaking up into distinct currents in entering the capillaries, and again running together and slipping into the larger tubes which commence the veins. It is a sight all should try to see, and the frog is not in the least injured by the examination. He is only held in position by a little tying with thread, as fully explained at the end of the chapter. A (fig. 61) represents a very small piece of the web in a natural condition. While this was under microscopic examination I painted between the toes with proof spirit. The skin immediately

lost some of its transparency, and very soon a pinkish tone began to appear to the naked eye. The alcohol had made the frog "blush" in his foot. B, in which the vessels are distended, is the appearance which was then presented in the microscope.

We can try a very similar experiment upon ourselves. Take two pieces of blotting-paper, dip one in water and the other in brandy or methylated spirit and water (half of each). Place

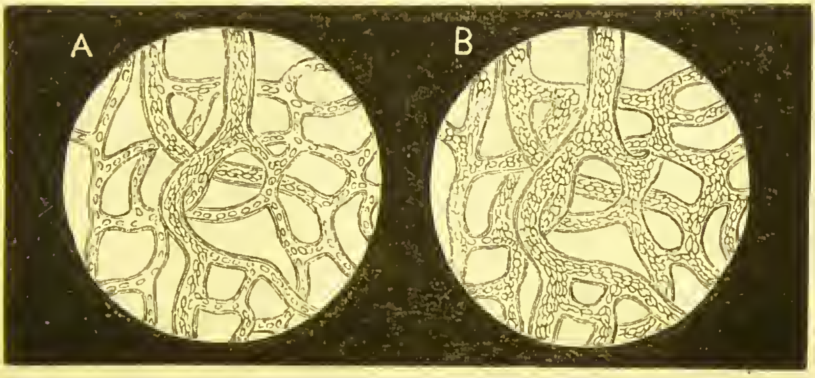

FIG. 61.—CIRCULATION IN WEB OF FOOT OF FROG.
(*Blood vessels only. Drawn from life.*)

A. Natural Circulation. B. Engorged Circulation of same induced by Painting with Alcohol.

the blotting-papers on the wrist, near to each other, and cover with two halfpence to prevent evaporation. In a few minutes the wrist under the alcohol will have slightly reddened, from the reason given.

Alcohol, when taken in small quantities, produces upon the body at large the effect the painting described produced on the frog's foot.

It begins not by giving strength, but by paralysing; the vaso-motor nerves being the first to show its action. The smaller blood vessels, no longer able to resist the blood pressure, swell, and as a consequence the cheeks are flushed, the ears become warm, the white of the eyes pink, and the temperature of the body at first rises slightly, for at the beginning of the process a little more blood than the average may be used up, but the temperature soon falls for two reasons, deficiency of oxygen, which we have considered, and the loss of heat brought about by bringing the blood largely to the surface of the body. For this warming of the surface, which is attended by a cooling of the interior,* allows the heat which we have produced to escape into the surrounding air, so that, as Dr. Richardson has so well put it, this seeming warmth "is a process of cooling." The man who is quickly spending his money may seem rich, but he is going the way to become poor.

An old illustration, which I suggested many years ago, I give now because I have not yet thought of a better. If I take a pudding out of the saucepan it at first steams and gives evidence of its great heat, but while it is so doing it is cooling rapidly. Soon, however, the hot vapour ceases to rise, and now the cooled outside, being a bad conductor of heat, protects the heat of the interior parts much as our own skin and

* The cooling of the interior is the result of carrying in much blood, which has lost its heat by exposure in the skin.

superficial fat tend to prevent the scattering of the heat of the body. If now I were to profess to make the pudding hot, by cutting it into parts, and turning the hot interior to the outside, an appearance of heat would certainly be manifested, and the hot vapour would again ascend, but everybody would surely see that this movement, so far from heating the pudding, was but the readiest way to cool it completely. So with our frame. Alcohol, while appearing to warm, only paralyses the true guardians of our heat, and so, to our loss, causes our hot blood to present its heat gratis to the air around, while, by reducing oxygen, it diminishes our power to replace what has been wasted. The full reason why alcohol instead of "keeping out the cold" lets out the heat is now before us.

Before leaving this subject we must notice just another method of regulating temperature which is very curious and beautiful, and which we may often have an opportunity of observing. If by any means we are beginning to lose heat much more quickly than we are forming it, a sudden chilliness of skin is often felt, together with a condition known as goose-flesh or goosiness. When lying in bed we are amply protected by the covering, and, therefore, the demand for heat production is small, but when we rise, the air around being cold, the leak of heat is at once great, and goose-flesh is likely to result. In fig. 62, (A) shows a section of the skin in its ordinary state, and here we note that the small hairs

which issue from it in great numbers, on the arms for example, are each provided not only with beautiful glands, *s.g.* (sebaceous glands), looking almost like bunches of grapes, and which secrete an oily matter bathing the hair sheath, but each has a small muscle (*m*) fixed near to its root or bulb. In the condition of goosiness (B), the

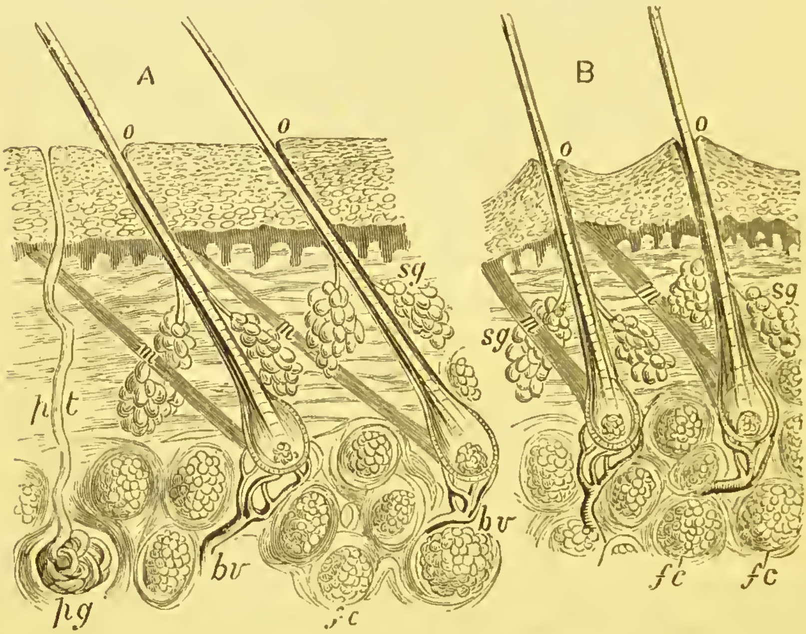

FIG. 62.—SECTION OF HUMAN SKIN SHOWING HAIRS.

A. Natural Condition. B. Condition of Goose Flesh; *pt.* Perspiratory Tube; *pg.* Perspiratory Gland; *bv.* Blood Vessel nourishing Hair Bulb; *m.* Hair Muscle; *o.* Opening through Skin; *sg.* Sebacious Glands; *fc.* Fat Cells.

muscle is made to contract, the bulb is raised, and the hair is drawn more upright so that the point (*o*) where it leaves the skin is lifted into a little prominence, and these prominences lying near to each other, give the appearance presented

by the skin of a plucked goose, and hence the term by which it is distinguished. The contraction of the muscle is a precaution of nature to reduce the amount of blood in the skin so that the leak of heat from the surface is reduced, bringing loss and production to a balance, and so preventing bad consequences from a fall in temperature.

Birds protect themselves in the cold in the same manner, and then their feathers may be seen loosely standing up. In their case as in ours, the large number of fat cells (*f.c.*) the skin contains assists greatly in preventing cooling, as fat is a bad conductor. Suppose in this condition alcohol be taken, the nerves causing contraction of the hair muscles (*m*) become paralysed, the muscles in consequence loosen, and the goosiness ends, but so far from this being a cure it is doubly injurious, for the leak of heat from the skin goes on unchecked, while the power to produce heat is lessened.

Experimenting upon myself, I find that other conditions being favourable, a draught of cold air down the back will produce very marked goosiness, and that a small piece of brown paper, protected above by a waterproof cover, and soaked in brandy or proof spirit if applied to a part of the arm for about an hour before the experiment will locally paralyse the nerves of the hair muscles, and that at the spot affected goosiness will not appear however noticeable it may be on the rest of the skin.

Returning to our consideration of the small blood vessels, we note that their enlargement, caused by the paralysing action of alcohol, passes away as the poisonous agent disappears, but continued indulgence so weakens them that they only in part recover. This is particularly noticeable in the face, where the enlargement frequently becomes quite permanent in hard drinkers, especially with those that pass much time in the open air, because cold increases the paralysing effect caused by the alcohol. Often in their case the superficial veins of the cheeks and nose will show as purple streaks ; the white of the eye for the same reason being continually red. The circulation in the nose being feeble, and its exposed surface large, it suffers worst, pimples are caused and fat deposited by the bad quality of the blood, as before explained, and so the poor nose swells, particularly at the end, often giving its foolish owner a character as unenviable as it is accurate.

That the action of alcohol on the nerve system is to predispose or make liable to attacks of various kinds, specially those that are inflammatory, is well shown by Huxley when treating of a different subject. His words, which ought now to be intelligible to the careful reader, so well apply that I give them verbatim :— "The practical importance of the local control exerted by the nervous system is immense. When exposure to cold gives a man catarrh (cold) or inflammation of the lungs, or diarrhœa,

or some still more serious affection of the abdominal viscera, the disease is brought about by the nervous system. The impression made by the cold on the skin is conveyed to the nervous centres, and so influences the vaso-motor nerves of the organ affected as to cause their partial paralysis, and produce that state of congestion which so commonly ends in inflammation." *

Here we see alcohol and cold when causing injury doing the same work precisely, paralysing, weakening, and tending to bring under the influence of disease.

The engorgement of the skin we have been considering is accompanied by a similar condition of the different tissues. The lungs, the stomach, the liver, the kidneys, the bowels, are all influenced, and as shown by Huxley's remarks, are all thus prepared for various forms of inflammatory disorders. The engorgement in the brain and nerves is extremely marked, because of the large amount of blood which under healthy conditions circulates through them.

If drinking be made a habit, the blood becomes ill-fitted for its work of nutrition, and the brain and nerve cells shrink, while the covering membranes thicken, and serum collects within them. The brain frequently softens, and undergoes fatty degeneration. The result is a weakened mind, and a will so enfeebled that no temptation can be resisted. Sleep becomes fitful, and fearful dreams awaken the sleeper. The muscles,

* Huxley's "Physiology," chapter ii., paragraph 25.

through the effect of the alcohol on the nerves, are in a continual tremor, and the victim becomes a weariness to himself. The foundation is certainly laid of such disorders as epilepsy, paralysis, and insanity. Alcohol being responsible for the sufferings of thousands of maniacs, doctors generally giving an estimate as high as 40 per cent. of the total number of lunacy cases as being traceable to intoxicants.

Nothing could be more dreadful than the picture this presents, for, according to this

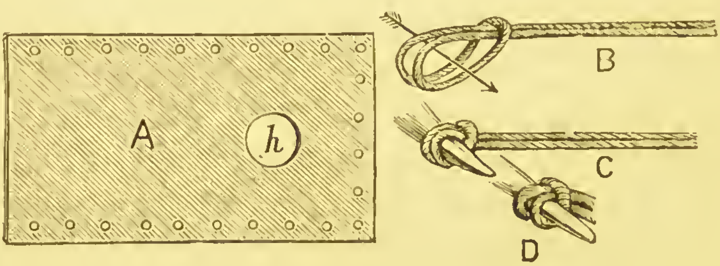

FIG. 63.—METHOD OF FIXING FROG FOR EXAMINATION.*
A. Frog Plate ; B. Slip Noose ; C. Noose Fixed ; D. Noose Loose.

estimate, not less than 8000 persons of the population of London alone have not been simply maddened, but have become actually mad through

* To examine the circulation in a frog's foot, cut a piece of thin board, A, fig. 63 (or thick cardboard, waterproofing the latter by soaking the material of a paraffin candle into it), to so fit the microscope stage that the $\frac{1}{2}$ or $\frac{3}{4}$-inch hole (*h*) will be opposite the microscope tube. The board should not be smaller than 5 in. × 2 in. Cut small clear holes as represented near the edge. Place your frog in a wet muslin bag with a draw-hem and string. Close up the mouth, keeping one leg out. Fix your frog gently over the part of the plate marked A, by tape or string. Make

drink. A misery, and often a terror to themselves and their friends, and all these, let us remember, who have run to such terrible excess, and have made such shipwreck, have begun by moderate quantities of the most sneaking enemy of our race.

slip loops B, over three or four pieces of wet twine or thread and pass one of the frog's toes through the first in the direction of the arrow. As he pulls, the knot will tighten as at C, now draw the foot into position, and fix the twine by means of the holes. Proceed similarly with the other toes so that the web is fixed flat over (*h*), and throw a strong light through it from the mirror. Keep the bag and the foot wet. If high powers are to be used, a cover glass with water must be employed, as every microscopist will understand. To liberate the frog, cut the twine as at D, and leave it to drop off. I have a frog that has done duty in this way frequently, without any injury.

CHAPTER XX.

Alcohol and the Vital Organs.

THE heart, as the great pump which propels the blood, is continually performing a tremendous amount of work, which is always, during health, proportioned to the needs of the body, and is, therefore, liable to considerable variation. The effort of standing is greater than that required to keep the body in the erect sitting posture, and, in consequence, a man's heart making 80 beats per minute, while he stands, will sink to 70 beats if he sits, and to 65 while he lies in complete repose. Running and leaping, with every kind of severe exercise, greatly quicken the heart's movement, which, as just now indicated, within certain limits, adjusts itself to the amount of effort put forth, whether it be bodily or mental.

The average number of beats of the heart of a man* is, roughly, 100,000 per day, or 70 per minute, and each contraction is made with such power, in order to drive the blood through

* The heart of the infant beats about 130 times per minute, and its rate lessens till adult life is reached. Woman's heart is somewhat more rapid than man's.

all the vessels, that it has been estimated the heart's day's work is equal to lifting 120 * tons one foot high, all the muscles of the body being only able to accomplish three times as much. This marvellous organ ceaselessly throbs on, and during a long life will make 3,000,000,000 beats without a stop, and propel through it half a million tons of blood, the while repairing its own tissues and taking its snatches of rest in the half seconds which intervene between its contractions.

When alcohol is taken the rate of the heart is increased, and according to some experiments made by Dr. Parkes, the number of extra beats per twenty-four hours rose with the dose as follows :—

1 oz.=1 pint	light ale	caused	4,300	extra	beats.
2 oz.=1 ,,	strong ,,	,,	8,172	,,	,,
4 oz.=1 ,,	sherry,	,,	12,960	,,	,,
8 oz.=1 ,,	whiskey,	,,	23,904	,,	,,

There are, at least, two reasons why the heart thus beats more quickly, but let us at first consider the principal one as it has been already explained in relation to another matter. The vaso-motor nerves (fig. 60) becoming paralysed no longer keep the small arteries in a contracted

* This estimate is bound about by difficulties, as will be seen from the conflicting results reached—

Houghton	calculated	124 tons,	one foot	high	per day
Dr. Andrew Buchanan	,,	42 ,,	,,		,,
Helmholtz	,,	122 ,,	,,		,,
Ranke	,,	278 ,,	,,		,,

condition, so that the energy* needful to push the blood through them is reduced. The heart, therefore, contracts more quickly simply because there is less to oppose it.

The steam fire-engines of to-day were unknown twenty years since, when men, volunteering their assistance, did all the pumping. The water, forced through a relatively small jet, resisted the action of the men, making the moving of the pump handles slow and laborious. If, during the operation, the hose pipe had been cut or broken, or the jet had been taken off, the increased opportunity given to the water of making its escape would immediately have allowed the men to pump more easily and more quickly, but the amount of work they would have put into the fire-engine would have been reduced. So with the heart, the greater quickness is not the result of increased energy, for alcohol reduces

* A little calculation, simply dividing 120 tons, reduced to ounces, by the 500,000 ounces of blood lifted by the 100,000 daily beats, will show that the 120 tons estimate, given before, supposes the heart's contraction to be equal to lifting the blood rather more than eight feet, as though a tube of that perpendicular height was attached to each ventricle and was always full of blood, which was delivered from its upper end, or including in the calculation, the fact that the left ventricle contracts with three times the energy of the right, the latter lifts an equivalent of four feet, the former, twelve feet. As the top of the head of a tall man is only twenty inches above his heart, and most of the blood is sent downwards, it is clear that this force in the contraction is to overcome the resistance of the blood-vessels, particularly those that are of small diameter.

the power of all muscles, and the heart, which is a very complex four-chambered muscle is no exception.*

* To more Advanced Students.—The position advanced by Dr. Richardson and many others certainly needs reconsidering for the two statements that the heart goes more quickly because resistance to it is reduced, and that it does more work because it thus goes more quickly, cannot both stand. Especially when a calculation follows, based upon the 120 foot tons for the day's natural work, stating that 25 per cent. increase in the number of beats increases the 120 foot tons by 25 per cent., an estimate which simply ignores that the resistance is lessened, and that the work of each beat is, therefore, less. The work done by the heart under the assigned conditions is not increased, it is reduced, for it can be easily proved dynamically that all quickening resulting from decreased load is accompanied by decreased output of energy. The heart necessarily follows the rule given, this view removing one of the greatest difficulties many have felt with regard to the supposed increase of power alcohol furnishes to the heart.

It has not either been ascertained that the circulation is accelerated as a whole by alcohol, and so far as reliable experiment has gone it appears to throw very considerable doubt upon the assertion that it *is* quickened, alcohol lessening the rate of circulation in dogs ; and in man rapid pulsations in febrile conditions have been clearly shown to be accompanied by a much retarded circulation, while the same is true when the veins are unusually dilated, especially if they at the same time have lost muscular tone :—The two conditions which actually obtain after alcoholic indulgence. It would appear at any rate that any considerable acceleration is impossible, for the veins become enlarged by their muscular fibres (which exist, although in less numbers than in the arteries,) also losing nervous control from the action of the alcohol, and in this way they are rendered unable to carry on the greater flow they at first receive from the capillaries. The large arteries are of course correspondingly narrowed in virtue of the elastic tissue in their coats. This

The injury done by the alcohol becomes evident when its first effect passes off, and the small arteries and capillaries begin to recover. The heart, badly nourished and nervously weakened, is now unable to bear its usual share of duty, and the rate of its pulsation goes down below the healthy standard.

We have certain nerves especially provided to control, check, and regulate the heart's movements, and these, when considerable doses of alcohol are taken, like the vaso-motors, appear to be taken off duty, and give the second reason at which we just now hinted for quickening the pulsation. The heart in consequence goes struggling on without restraint, labouring heavily although accomplishing less, because its powers are reduced ; just as a man who in health may lift 200 lbs., and next moment feel that he is

shows a reduction of internal pressure which is the direct consequence of a reduced heart pressure, for the pressures in the aorta and the left ventricle are about equal. We are then almost shut up to the conclusion that as the heart beats more frequently but can only deliver the blood returned to it by the veins, the amount of blood thrown out by each pulsation is small, giving us another reason for supposing that the work accomplished under alcohol is not increased, but diminished, alcohol not being a stimulant, in the sense in which the word is frequently understood, but a narcotic. It is possible that greater effort may be made by the heart in consequence of irritation at some of the nerve centres but it is at least equally likely that disordered and excited movements may be the result of narcotic action upon the vagus or inhibitory nerves, which nerves tend to check the heart's pace, and experiment has shown, in several animals, that section of the vagus produces a more rapid contraction of the ventricles.

again ready for a similar effort, while if he be ill, and he strains till he raises far less, he all but sinks with the induced exhaustion. It is not therefore unlikely that part of the reduced pace of the heart *after* alcoholic drinking is the result of undue fatigue.

The heart, because constantly at work, is more liable, through alcohol, to suffer from fatty degeneration (see page 189) than any other part of the body, and where this occurs, its powers constantly diminish as its muscle fibres become displaced by unhealthy fat cells.

The blood vessels themselves do not escape injury; their walls soften and degenerate, becoming in heavy drinkers peculiarly liable to rupture, so that internal bleedings and apoplexy may at any time occur. While, however, it is only in the case of very intemperate people that serious disease of the blood vessels must be looked for, it is equally true that every time alcohol is taken in even small quantities it contributes something towards a weakened condition both of the heart and the vessels. It has been shown that although small quantities of CO_2 in the air above the amount that is usual do not produce marked effect, still that a continued breathing of such air causes the very small injury to accumulate in such a manner that life is actually shortened thereby. So with alcohol. Small doses produce no marked effect, but if these be continued, the result accumulates, and a decided reduction of the period of life is

the consequence, as fully explained (Chapter XXII.).

The lungs are irritated, the delicate membrane of the air cells is thickened, and the work of oxygenating the blood thus made more difficult. The engorgement of the blood vessels and the weakening of the controlling nerves predisposes to bronchitis and inflammatory disorders of the chest. Statistics have shown that those suffering from consumption reach a fatal termination more quickly if they have indulged or do indulge in alcoholic liquors, and that in proportion to the amount consumed.

The immediate and first effect of alcoholic drinks upon the liver is to increase the flow of bile, because the amount of blood in the capillaries is made greater, but the influence on the secreting cells soon reduces their power, and then less bile is separated from the blood. The liver has already received a good deal of attention (Chapter XV.). Its fatty degeneration was not, however, mentioned since this matter has been explained later. From this cause it usually suffers terribly. Its dark, healthy colour gives way to a pale olive, it greatly enlarges and becomes watery and flabby. In this condition it cannot remove the waste and deleterious matters from the blood, which is its duty, and the whole system suffers.

The kidneys in the same way are not only damaged but made peculiarly liable to attacks of various forms of disease. Indeed, alcohol ter-

minates life in by far the greater number of cases, not by itself destroying, but by bringing the body into that plight in which adverse conditions cannot be resisted. In certain epidemic diseases, such as cholera for instance, it has been again and again remarked that intemperate persons are attacked in a far larger proportion than the temperate, and that their attacks more frequently prove fatal. Numberless cases of death, which are ascribed to all sorts of causes, are really due to alcohol, which has made all things ready for the reception and development of the disease. Without the alcoholic indulgence the disease would either not have occurred, or would not have been fatal, and therefore alcohol is the true cause of death.

It should be carefully noted that as life advances the vigour of youth is not maintained, and that the comparative weakness of later life is always associated with something very like to fatty degeneration, which does not imply that the body grows bulky, it merely means that the active tissues become altered in character, their contractile or more vital parts shrink and give place to others without contractility or with lower vitality, and then diseases more easily make an inroad and work out a fatal result. Alcohol, we have shown (page 185) brings on at once the conditions which mark old age, and so most surely shortens life.

It is possibly difficult for the learner to understand why an agent that is so uniformly injurious

as alcohol should so commonly, when once taken, produce a desire to take it again, and that every gratification of that desire should be followed by a more earnest demand until at last it cannot be resisted.

It will be remembered that the stomach puts on a tolerance (page 161). In like manner certain changes are produced in the body generally, by which it puts itself, as it were, into a condition of defence against the alcohol attack. Whilst the alcohol is regularly taken this condition of defence does not make itself apparent, but if the alcohol be discontinued a sense of discomfort is occasioned by it, which leads the victim to imagine that the alcohol is really necessary. An illustration may serve as an explanation. Suppose I am making my way against a head wind on a rainy day, I hold my umbrella in front of me, and have to lean forwards considerably, or I should be blown over backwards. I give myself an inclination the opposite of that which the wind would induce, so that the opposing tendencies may destroy each other :—in a word I put myself into the correct position for the circumstances in which I find myself. If now suddenly the wind ceased I should be likely to fall flat on my face. Should I therefore be foolish enough to declare that a head wind was necessary to hold me up, as without it I could not get along? The alcohol is the head wind; it hinders and delays, and it only makes itself appear to hold me up, because I have put myself

into a condition of defence. I am leaning, as it were, against its inroad that I may suffer as little as possible therefrom.

The last difficulty suggests another of very great importance. Are there no conditions in which alcohol can be useful to the body? We have settled already that it is not a food, although it may be oxidised, the question now asked is equal to saying, can it be a medicine? Imagine you have a sewing-machine which works badly, and some one instructed in this kind of mechanism says, "I see what is the matter; the screw at the top which regulates the tension is too slack, it wants tightening;" he performs the operation, and the sewing-machine immediately is much improved. A friend who has been present goes home to her sewing machine which always has given satisfaction, and says I will tighten the screw at the top in mine. We know the result: the machine now is out of condition. The turning of the screw represents the action of alcohol; which does not sustain function, but alters it. By making an alteration it may possibly do good, for it may alter that which is wrong to that which is right, but it is immensely more likely to do harm, and it should be used only by those who have especially studied its action. If the body is in health alcohol must inevitably bring about an alteration from the health standard, and should be avoided. If it is out of health the chances are all in favour of its making bad worse, though it cannot

be denied that cases do occur in which it may be temporarily useful.

I will give you an extreme case as an example. Suppose that the heart from some cause (a sudden one perhaps) is so weak, that it is fluttering instead of beating. It is failing to get the blood round its accustomed circuit, and without help death is likely. In this crisis alcohol is generally given. It further weakens the weak heart, but it so greatly reduces the burden that the heart overcomes it and the patient rallies. Don't let us imagine that here the alcohol has cured the weak heart. No ; it has only enabled the heart to tide over a difficulty, while its action has really tended to make the heart weaker than before. The whole case is very like that of a loan at high interest to a man already in debt. The alcohol, under such circumstances, may have been necessary, but after all it is but a necessary evil, which must only be appealed to in necessity, or, as a heart weakener, it will certainly increase the bad symptoms it is intended to remove. Don't let any of us be afraid of acknowledging that alcohol is a drug. If it is so, it certainly must not be used as a part of our diet, for this is the mistake which has made it the greatest enemy of our race, destroying in these latter days more lives than war and pestilence, and breaking more hearts than all other causes of sorrow heaped together.

Although much mischief has arisen from supposing alcohol to be a sort of universal medicine,

far worse results have followed the mistakes which have been caused by calling it a stimulant, which is generally supposed to imply that alcohol imparts fresh life, gives new power, and increases our ability for work of every kind. The origin of the word stimulant is the Latin *stimulus*, which meant a pointed piece of iron used to drive oxen when at work. Such a stimulus or spur it is evident cannot put increased power into any creature, but can only by giving pain drive it to greater effort in using up the forces it already possesses, and which we now know must be derived from its food. The whip may make the tired horse go faster, but it only increases the exhaustion from which the animal must at length stop if the stimulant—*i.e.*, the whip, be continued. Alcohol is a stimulant only because, as we shall now explain, it hastens exhaustion, and wears out the powers of the body held in reserve before it was taken.

Our marvellous frame has not only the power of self-repair, it also holds a large power of self-cure struggling to set right whatever may have gone wrong. When the unwise snuff-taker irritates the delicate lining membrane of his nose, Nature shows her displeasure by setting up a sort of spasm, the uncontrollable and almost explosive sneeze, by which the air is driven violently out of the lungs *through the nose* in order to clear out the offending powder. But if through some inflammation in the lungs, a mucus collects in the breathing (bronchial) tubes so that

air could not reach the air cells (Chapter XVI.), a similar rapid expulsion of air takes place in order to remove the obstruction, but this time the air escapes by the mouth, and the nose is not at all affected. Thus, then, Nature manages for us the sneeze or the cough in such a wise way that the purpose she has in hand is exactly accomplished. If again, by some sad accident, the main artery of the leg be broken, bleeding would soon cause death unless the doctor tie the artery ; now Nature must to work to set things right. The leg needs blood, and its old channel of supply is gone. But she is equal to the occasion, and some small blood-vessel or vessels, which by their position bridge the wound, are selected by her hidden wisdom, we know not how, and begin to grow in size, at an enormous rate, until in a few hours a sufficient channel is opened up and the leg gets all the supply that may be necessary. Similarly, when alcohol, or any other narcotic, is taken, the powers of Nature rise to set right what has gone wrong—*i.e.*, to repel the enemy, and this occasions that excitement and disturbance amongst the several organs which has so often been mistaken for an increase of power.* A narcotic tends to produce sleep, yet

* It has more than once been asserted that the action of alcohol is the same throughout, and yet it is admitted that the first symptoms are of the nature of excitement, the late ones of stupor. There will be confusion of idea, unless we look at the reasons of things. Narcotics which tend to produce sleep almost always are accompanied by the indications now given. The first, is the

small doses commonly cause excitement, but the excitement is only indirectly due to the narcotic.

Imagine that as we study this matter, we suddenly hear without, the angry snappings of some large dog ; and now the door flies open, and the furious animal, apparently mad, is in our midst ! Our calmness at once is gone, and all is activity, our intense anxiety to save ourselves from the dreaded bite by destroying or driving out the savage beast impelling to tremendous exertion. That mad dog is a stimulant, and such a stimulant is alcohol.

Having accomplished our purpose, should we resume our study, saying What new power that dog put into us ! When *he* appeared *he* so filled us with life, that none could rest, and our energy he so increased, that our activity was an astonishment to our very selves. Oh ! that we could constantly have a mad dog amongst us to increase our vitality and inspire us with vigour. No, we should with throbbing hearts, trembling knees, and quivering lips relate the power the dog had taken *out* of us. We should be conscious of the price the excitement had cost, for the exhaustion of stimulation would be upon us. So with alcohol, nature will none of it ; she

result of nature in conflict ; the second, the result of her defeat. The tendency of the narcotic has undergone no change, the outward indications only vary. The first, shows nature rousing herself to make narcotic action impossible, the second, is the narcotic action itself, when reaction is overborne and nature has fallen under the spell of the drug.

rises to defend us, and the effort of expelling or destroying it, uses up a power all our own before the alcohol was taken. We are losers, not gainers by the encounter. Alcohol is a weakener, not a giver of strength. It does not keep us up, as people ignorantly say; it keeps us down. Who would be foolish enough to believe that the *whip* makes the carriage go faster. No, the horse goes faster using up and wearing out his waining strength to save his poor back; and so the poor drinker for a little goes faster, using up his life power to clear his blood of the enemy. He is in a condition of continual internal warfare; his vital powers straining to drive out the foe, which he in his folly is ever readmitting at the gate. If alcohol gave new power, those who took most of it should live longest, whereas presently we shall prove that those who take none live out their days, and that all drinking even of the smallest quantities reduces the term of life.

SECTION IV.

ALCOHOL AND THE NATION.

CHAPTER XXI.

Waste and Woe.

WE have traced the mischievous action of intoxicating liquors upon the consumer, and it now remains for us to trace their effect upon the whole population, for in the unhappy story before us we shall find that the innocent suffer through the guilty. In 1876 the drink bill of Great Britain and Ireland reached the enormous sum of £147,288,759, and though, since it has decreased somewhat, it still stands at that which almost baffles the imagination, the total for 1888 being £124,603,939.

Let us give a little attention to these figures, in order that we may the better understand what they convey. A sovereign is no mean power; often a working man has less with which to keep his home together for a week. Yet how small it is, only $\frac{7}{8}$-inch in diameter, and if sovereigns be placed in line 41 will scarcely

reach a yard. Were these ours to wisely help the needy, how many hearts could we cheer? what delight could we give! The very thought of it almost brings the tear of joy into the eye. But, oh! these millions, what could they not have done? If we place *them* in line how far will *they* reach? How they could have banished want and covered the face of the land with rejoicing! If our home be near the great Metropolis, we may start from our door, and one by one we make the golden chain to the Chatham and Dover Railway, taking care to keep all the sovereigns in touch up the stairs to the rails, and now we follow on through weary miles till the very end of the railway is reached. The Channel is before us, but we continue our line to France, and on and away to Paris, and then south, crossing mountains, forests, and rivers, till we ascend the slope of the Pyrenees, and turn the crest down the southern face into Spain, to traverse the whole of this large country. The rock of Gibraltar is climbed when we cross the Straits, and plant our foot in Africa with the golden coins an unbroken cord from our very doorstep, and still enough remain to continue the work about 560 miles into the interior. We are older than when we started our 1720 miles of chain, for if we have worked ten hours daily, and have placed a sovereign each second, our task has occupied rather more than 11 years.

How dreadful, how unspeakably dreadful, is this waste! While it goes on many are dying

actually starved, and tens of thousands have their sad lives pinched out of them before their time for lack of ordinary comfort, their shivering, half-fed, half-clothed bodies a prey to the wind and the frost. Nearly if not quite half the sum spent by the country in the purchase of alcoholic intoxicants comes from the pockets of working people, whose folly in this matter is the most fruitful source of poverty and distress, the gross result being characters ruined, homes desolated, hearts broken, health shattered, cruelty, wretchedness, and wrong, which can neither be imagined nor described. Could this stupendous outlay be devoted to profitable uses the country would soon be so prosperous that its condition would be utterly changed.

The money spent on drink is equal to the cost of bread, butter, and cheese, and about three times the amount expended in woollen and worsted goods. It is nearly twice the total receipts for all passenger and goods traffic on all the railways, and more than the rents of all the farms and all the houses in the United Kingdom.

The mere manufacture of intoxicating liquors involves a waste of the fruits of the earth perfectly appalling. Dr. Dawson Burns points out that we are importing something like £60,000,000 worth of corn yearly, and, at the same time, we are annually destroying 75,000,000 bushels of grain in the production of alcohol, either in brewing or spirit-making. Each bushel would yield 40 lbs. of flour, or make 15 4 lb. loaves,

giving a total of 1,117,500,000 loaves of nutritious bread, a store sufficient to supply 180 loaves, or 720 lbs. of bread, yearly to every family in the country. I find such loaves would be about 7 ins. square at bottom and 8 ins. high, and would, if placed as paving-stones, form a road 10 yards wide and 2400 * miles long.

Mr. Hoyle has shown that the average destruction of corn in this horrible drink trade during twelve recent years has been so immense, that 2,000,000 acres, equal to the 1-16th of England, or the total area of Middlesex, Kent, Surrey, and Berkshire would be required to grow it, and this leaves out of view the tremendous amount of saccharum (Chapter XI.) we import for brewing purposes.

The tale of loss is, unfortunately, only half told, for a cruel cost falls upon the whole nation in dealing with the mischiefs resulting from the consumption of intoxicants. A short time ago I visited a large lunatic asylum. Here were 2000 afflicted persons supported out of the rates † to which all have directly or indirectly to contribute. If the usual estimate be taken as correct that 40 per cent. of the insane owe their condition in some way to drinking habits (perhaps not their own), then we see that in this one asylum the cost of 800 people was directly chargeable to

* The estimate generally given is too small.

† If a father in a family has to dip deeply into his pocket to pay a rate, the children of the family cannot have so many wants provided, and so the children even, indirectly, pay their share.

intoxicating liquors. Again, suppose only 100 of these people were men who, if in health, could have supported their homes, and that through their failure these homes had in some way to be wholly or in part kept going by charity or by the poor-rates, we have another and a heavy money charge to bring against drinking, and when we learn that in Great Britain there are more than 100,000 persons in lunatic asylums, we see that in this one way the loss to the nation is very large indeed.

Everybody must notice that as men spend more in intoxicating drinks they earn less. The bad spending of Saturday night and Sunday makes Monday also a wasted day. Mr. B. Whitworth said in his evidence before a Parliamentary Committee—"We find from experience that the men will not come to work on Monday morning in sufficient numbers to make it worth while to put the machinery in motion. Even if they do, they are unfit for work, and we find it such ineffective labour that we do not start till the Tuesday." The result is a loss of £35,000 per year on that one concern alone. Mr. Whitworth's case represents what is occurring nearly everywhere. The muddled brain and the unsteady hand cause countless blunders and waste of material, all of which means so much loss to the country. Of what a number of working men is it true, that through the public-house the home suffers, habits of thrift are forgotten, and when work grows scarce, or illness comes, parish relief

is immediately required. If total abstinence prevailed, working people would be in a condition of permanent independence, instead of so frequently standing, as it were, upon the very fringe of pauperism. It has been shown that 46 per cent.* of the persons receiving parish relief are either drunkards or persons dependent upon them, and since the cost of poor-law relief for England and Wales is about nine million pounds, it is easily calculated that every man, woman, and child (not being a pauper) in the country has to make an average contribution of 2s. 8d. to support drunkards or their families.

A still more distressing view of the case demands our attention. Could intoxicating drinks be banished, our prisons would soon become nearly empty, nine-tenths of the police unnecessary, and the great cost of administering justice remarkably lessened, for those who are in the best position to form a correct judgment say that nine-tenths of the criminals become such in some way through drink.

Mr. Justice Hawkins at Bradford Assizes said: "I do not hesitate to affirm that the great majority of the crimes that come before me can be traced, either directly or indirectly, to the influence of drink." Five years later, at the Durham Assizes, he gave even stronger expression to the same opinion: "Every day I live

* In the absence of intoxicants prosperity would so increase that pauperism would shrink to a fraction of its present proportions.

I come more firmly to the conclusion that the root of all crime is drink. I believe that nine-tenths of the crime of this country, and certainly of the county of Durham, is engendered within public-houses."

Mr. Justice Denman at the Exeter Assizes, 1878, spoke thus: "On one occasion in a northern county I sat to try a calendar of sixty-three prisoners, out of whom thirty-six were charged with offences of violence, from murder downwards, there being no less than six murders amongst the thirty-six. In every single case, not indirectly but directly, these offences were attributable to excessive drinking."

Baron Huddleston stated at Swansea Assizes: "Of the forty-four cases down in the calendar, I find almost all traceable, directly or indirectly, to the detestable habit of drinking."

Baron Dowse * at Dublin remarked: "I find that drink is at the bottom of almost every crime committed in Dublin," and further observed that even cases that "had no apparent connection with drink at all," if closely investigated, as he himself had frequently investigated them, would be found to have their origin in drink.

This kind of testimony can be multiplied to any extent; but enough has been said, yet two or three facts concerning foreign parts will be useful as serving to show that drink is everywhere the same—a manufacturer of criminals, and a destroyer of every impulse that is noble

* Prize Essay by Lacey.

and true. The 1st Battalion of the Leicester Regiment, stationed in India between 1884 and 1886, had the following history. The non-abstaining soldiers had (in proportion to their numbers), for three different kinds of crime, eight times, forty-seven times, and twenty-seven times as many punishments inflicted as the abstainers incurred, while the non-abstainers, who received so very large a share of the punishment and disgrace, stood correspondingly low with regard to rewards and good conduct marks.

In Belgium, in 1873, through an alteration in the law of licenses, the sale of intoxicants was made more easy, and in consequence very many persons began to deal in them. The bad effect was soon apparent. In fifteen years intemperance had so extended that the sale of liquors had doubled, but in the same period misfortunes had increased, suicides, insanity, and poverty had grown most alarmingly, trade had languished, discontent had become common, and the prisons too small for the ever-multiplying prisoners, which were now four times as numerous as at the beginning of the experiment. The law which had worked such terrible mischief was again altered on 8th September, 1888.

Where the experiment has been tried of excluding the public-house, wonderful prosperity and freedom from crime have followed. One example must suffice. In the town of Grinnell, Iowa, U.S.A., alcoholic drinks are not allowed to be sold,

and for twenty-five years no one has been sent to gaol, to the poorhouse, or to the penitentiary.

What can be the explanation of the foregoing extraordinary facts and statements ascribing to alcohol the largest part of crimes of all kinds, and making it almost totally responsible for those of violence? How is it that this dreadful agent appears to rouse all that is evil, and quench all that is good in human nature? From what we have learnt, it is clear that the brain and nerves under its action, from the very first, pass into an unhealthy condition, and that if drinking becomes a habit, a diseased state of a more or less permanent kind is set up. Every time the horrible narcotic is indulged in, the thinking power, the will, and the judgment grow weaker and weaker in proportion to the dose, until the lower feelings and passions, freed of all control, run riot, like a dog which has broken his chain. The least excitement towards anger, having no check, is allowed to run wild until it becomes fury. A man who is kind, it may be, when sober may thus turn savagely cruel when intoxicated. His cruelties are committed without reflection, and without regard to consequences, for reflection and prudence are alike dead; his whole mind being at best muddled and inactive. He is no longer a reasoning being, the master of his own actions, directing and controlling his impulses, but a self-made maniac. His impulses are now his master, and control him. And quite possibly when the alcoholic madness, for such it

is, has passed away he remembers nothing of his doings, and is only forced to believe in them by the sad evidence of their reality left behind in mischief which cannot be undone. Drunkenness unhappily is too often then urged as an excuse; but when the drunkenness is voluntary, it is clearly the after effects which condemn the drunkenness, not the drunkenness which excuses the after effects. Here, for mercy and justice sake, we must say that drunkenness is often not voluntary. As we have just shown, the dreadful narcotic slowly but surely weakens the will and ability to resist, while it makes the temptation grow until its victim is in its power. He may know full well that he is in the grasp of the enemy, and that if he continues in the downward road disgrace and death itself cannot be far off, yet he cannot shake himself free, he is carried captive by alcohol at its will. He is a slave to drink, and for him the sunlight of hope is blotted out by the dark clouds of despair. What an argument in favour of total abstinence is this. He who says "I will not drink," and does not, is free; while he who says "I would that I did not drink, but I fall because I cannot resist," is a bond slave.

Thinking over the bare outline of facts given, we can see how drink not only injures the drinker, but the whole community, upon whom falls the sad contagion of every violation of decency and good order, besides a partnership in the suffering involved in wrong-doing, to

which we must add a money burden calculated by those who have especially studied the question, as at least equal to the total cost of the drinks themselves.* It is sometimes said of the poor drunkard, "He is no one's enemy but his own;" a greater mistake could scarcely be uttered. The drinker is the enemy of his country, an injury to all, not only on the low question of money, but on the higher one of example. Young people who read these pages, may such never be your case! May your life be one of thankful enjoyment, and may your aim and your delight be to help, upraise, and brighten all with whom you come in contact!

While it is impossible to deplore too deeply the losses to which the innocent are exposed, let us rather think of the woes of the victim, and those immediately surrounding him, for could we but hear the thuds of the blows and falls, the babel of oaths and cursing, and the chorus of shrieks proceeding from the homes of the drunkards of any one of our cities on a single Saturday night, should we not, with hearts quailing and cheeks blanched, determine that, with God's help, we would, by example at least, set our faces against the right-hand helper of the evil one.

* This leaves out of view loss through shortened life as shown in the next chapter.

CHAPTER XXII.

Drink and Death.

In the foregoing ehapters it has been shown that alcohol in so-ealled moderate quantities, as well as in those that are admittedly excessive, hinders the digestion of the food, poisons the blood, disorders the brain, beelouds the mind, paralyses the nerves, weakens the museles, and damages without exception the vital organs. It must therefore, make the body more subjeet to disease and shorten the term of human life. A study of the following facts and figures will show how sadly this is true.

Happily in the case of certain life assurance offices, we not only get an exaet and duly eertified statement of the duration of life amongst those assured, but as the latter are divided into two sections, the abstainers and non-abstainers, we are able at onee to establish a comparison of the duration of life between these two elasses. The comparison having additional value from its lying between two large groups of persons, under the same general conditions save with the one exception already stated. The comparison

too is not between teetotallers and drunkards, but between abstainers and moderate drinkers, as any person given to habits of intemperance would on that account be refused admission into the ranks of the assured. His life in consequence of his drinking being so uncertain, that it would not pay the office to accept him.

In the year 1840 was founded The United Kingdom Temperance and General Provident Institution. The fact that abstainers lived longer than others became more and more obvious, and led in 1866 to the division of the policy-holders* into the two sections previously mentioned, in order that each might justly participate in the profits. The results of this division have been to prove most conclusively that moderate drinkers die more than 25 per cent. faster than total abstainers.

Tables have been constructed from which it is possible, by taking averages, to calculate with surprising accuracy the number of deaths that

* There are several ways in which a life may be assured, but the usual form is as follows. The policy-holder agrees to pay a certain sum yearly till death; the Assurance Company undertaking to pay an agreed amount then to his family. A young man 21 years of age would on the average live about 40 years. He by paying something less than £2 yearly, would secure £100 to his survivors. If he lived 50 years the Insurance Company would make a considerable profit, if he were to live only 20 years his family would be gainers. The Companies desire naturally to accept only those that are likely to live fully the average period. They, therefore, refuse the sickly or diseased. Those that they accept are called in consequence "good" or "selected" lives.

will occur under ordinary circumstances in one or more years amongst any number of persons* whose ages are known.

Such calculations have been made by an accomplished actuary annually, and for each period of five years since 1866 in the General Provident Institution, and the total result for the whole period, from 1866 to the beginning of 1890, shows that in the ordinary section 6894 deaths were expected, and 6645 occurred, while in the temperance (total abstainers) section 4542 deaths were expected, and only 3198 occurred.

It here appears that the moderate drinkers, although their lives were selected, died up to 96 per cent., while the teetotallers died to the extent of only 70 per cent. of the calculation, or putting the case after the manner of Dr. Ridge in his excellent card on this matter:—If the moderate drinkers had been abstainers their deaths would have been 4854 instead of 6894, or in other words through moderate drinking 2040 of the policy-holders were in their graves, at the date to which the calculation related, who would have been living had they totally abstained, or had the total abstainers become moderate drinkers, 1180 of them that were then living, would already have been mourned by their families.

Turning to the Sceptre Life Association, which also divides its policy-holders as abstainers and non-abstainers, we find that in twenty-two years the expected deaths amongst the former were 300,

* Averages are only applicable to considerable numbers.

while the actual deaths have only been 134, or less than 45 per cent., while in the "general" or non-abstaining section the numbers stand as 685 and 608, or more than 88 per cent. Examples of a similar nature may be almost indefinitely multiplied, but enough has been said, for facts like these admit of only one possible explanation: —Alcohol, as it has been represented throughout this book, *is* an enemy to human health and life. Its so-called stimulating action is but its active exhaustion of energy which brings death nearer.

If, then, moderate drinking is so destructive, what is the effect where there is a constant temptation to excess? As a matter of business it has been discovered by assurance offices that publicans, in consequence of their unfortunate connection with alcohol, have their term of life so extremely shortened that their assurance almost invariably causes loss to the company accepting them. As a consequence, they are now refused by nearly every life office for the reason stated on the notice, of which a copy is given below.

GENERAL ASSURANCE OFFICE,
103 Cannon Street, LONDON, E.C.

In consequence of the excessive mortality experienced in the case of INNKEEPERS, whose Lives have been Assured with the Company, it is hereby notified that from this date the Directors will not undertake these risks on any terms.

February 18, 1881.

The Registrar-General for England has given

a number of tables in the supplement to his forty-fifth Annual Report, which confirm what has been already said, in a manner which is almost as sad as it is conclusive. Upon the actual mortality obtaining in the country in the years 1880-82, he there shows that, between the ages of twenty-five and forty-five years, the annual death rate of 1000 "clergymen, priests, and ministers," was 4·64 ; of barristers, 7·54 ; of brewers, 13·90 ; of innkeepers and publicans, 18·02 ; of inn and hotel servants, 22·63 ; or 4·87 times as great a death rate as that of the most healthy occupation ; it is also singularly apparent that the death rate grows in direct proportion to the known propensities to tippling in the three last classes.

The Registrar-General also has calculated from the details before him the "comparative mortality," obtaining during the years 1880-82, in the several occupations enumerated in fig. 64. The table expresses, according to the length of each horizontal band, the number of deaths occurring annually, and in each case, amongst 64,641 individuals between the ages of twenty-five and sixty-five years. The two perpendicular lines form the basis of the comparison, as the one on the right (1000) gives the annual number of deaths amongst the before-mentioned 64,641 males throughout the country, the one on the left (804) the number occurring in selected healthy districts. The appalling mortality of those connected with the liquor traffic is so self-evident as to need no comment.

Dr. Dawson Burns, in a most instructive tract,* compares the sick and mortality lists of various abstaining and non-abstaining Benefit and Friendly Societies, in which the former come most astonishingly to the front. The Rechabites are compared with the Oddfellows, to the great disadvan-

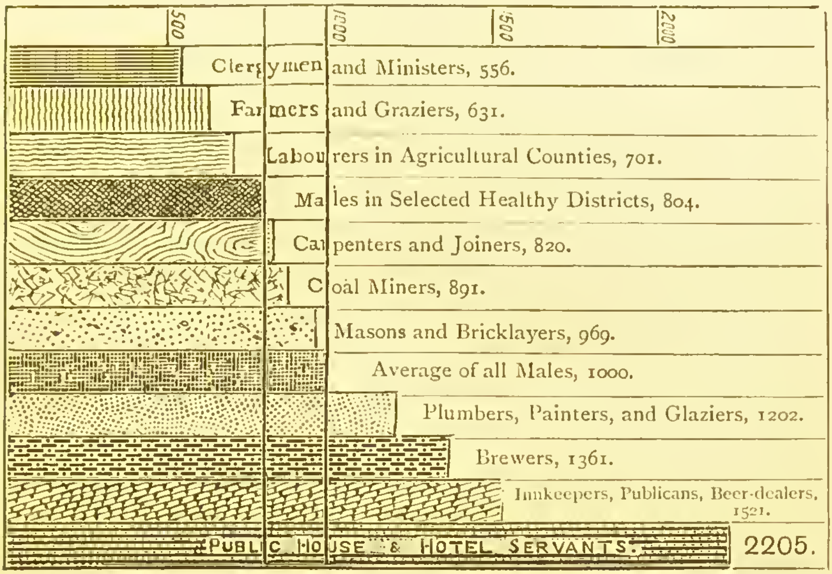

Fig. 64.

Comparative Mortality in some Professions and Callings.

tage of the latter. Covering the same five years, the average sickness per member of the Rechabites is 17 days, 12 hours; that of the Oddfellows 65 days, 15 hours; while the average annual mortality amongst the abstaining Rechabites was 1 in 140, it was amongst the Oddfellows, 1 in 54.

* "Vital Statistics." National Temperance Publication Depot.

Between the Sons of Temperance, and the Manchester Unity of Oddfellows, and the Foresters, we find similar and utterly incomprehensible disparity if we do not agree that death lurks in the intoxicating cup, for the average duration of sickness amongst the Sons of Temperance is only slightly more than one-fourth of that experienced by the two latter societies.

Dr. Burns also argues for the London Temperance Hospital, established for the noble purpose of showing that disease could be treated without the continued intervention of the great disease producer. Here alcohol *is* admitted as a drug, although it is certainly not regarded as a universal medicine, for only in one or two cases has it been administered by the able physician, Dr. Edmunds. The result is most satisfactory, and proves the correctness of the theory of the founders that alcohol is not only not needed, but is generally an impediment to recovery, for the death rate compares most favourably with that of other similar institutions.

Dr. Norman Kerr, in two scholarly papers, read before the Social Science Congress, and the Harveian Medical Society, states that he is convinced that the actual number of deaths from drink, in the United Kingdom, reaches the terrible total of 120,000 yearly; 40,000 being the direct result of personal inebriety, and 80,000 being the indirect result of intemperance in others.

Some dispute the foregoing figures, although few would appear to have a better title to an

opinion than Dr. Kerr. At any rate, the mortality from drunkenness is enormous, and when we add to the loss through the deaths, the reduced ability for work which comes upon every drinker, we have an indirect diminution of the power to accumulate wealth by the community, which is well-nigh beyond belief, and which demands our serious attention.

The infant is a care and a cost, and much has to be expended upon it before it can even support itself. When the age for profitable labour is reached, a debt to the community, for up-bringing, education, and training has to be paid off. Then only can the man or woman, by producing, in value, more than the total sum of personal expenses, begin to add to the wealth of the community of which he or she is a member. A calculation has been made, that the average value of an English life, in virtue of this ability to labour productively, is £159. Accepting this conclusion, let us calculate the loss which will have to be added to the £250,000,000, or thereabouts, arrived at in the last chapter, and let us also take care that our data shall all err, if at all, on the side of reducing our result. If the average duration of life in England be fifty years, and the period of remunerative labour commence at twenty, a reduction of one-fifth of the whole (considerably less than the incontrovertible statistics of the Life Assurance Companies would justify), reduces the adult profitable period by one-third—*i.e.*, if Great Britain adopted total abstinence,

£53,* as an increased value arising from increased duration, would have to be added to all lives now outside the teetotal army. Assuming the number to be 30,000,000,† an addition of £1,590,000,000 would be made to our accumulating wealth every fifty years, which sum is now dissipated by the shortening of life through drink. A far larger sum, is, however, lost to us by the lowering of the vitality and energy of the nation from the same reason. By this the output is most seriously diminished; and although it may not be possible to measure the loss, it may, without any fear of exaggeration, be concluded that in Great Britain, all causes considered, we are impoverished by and through intoxicating drinks, in a crushing total of one million pounds every twenty-four hours.

Our task is drawing to its close, but the writer feels that he cannot part with his readers till he has put the case briefly from yet another side. Voices come to us from love of health and wealth, regard for character, enjoyment of mental and physical ability, asking us to abstain. These appeal to our instinct of self-preservation, and only at our peril can we disregard them, but are there not other voices coming to us from this sorrow-stricken world, from our brothers and sisters who have fallen, and been made

* To this, as the mathematical student will see, should be added one-third of the cost of upbringing, for which we have no data. It would probably more than double the amount taken.

† It is right to include the whole population, of whatever age, because the £159 has been arrived at upon that basis.

sinful, sad, and sickly, through this dreadful and deceptive agent, and do not these plead with us with a pathos that no true heart can resist? Are they not in the name of all that is pitiful asking, along with those still unvanquished by the foe, that for their sakes we should abstain. Mingling with this cry for help comes the mute eloquence of the little ones not yet blighted by the contagion of evil example. Oh dare we stop our ears, and with Cain reply, "Am I my brother's keeper?" We cannot live to ourselves if we would, we are ever impressing our own mental and moral likeness upon those around. In the studio of the photographer we in a moment of supreme stillness fix our second self upon the sensitive plate, and so in the world at large we are unceasingly exerting an influence, insensibly instilling our character and habits into our fellows. May our influence, because, as we said at the beginning, we are led by all that is good and true, be heroically exerted for man's uplifting. It can only be so exerted by our joining those who are striving by precept and example to do something to deliver men from alcohol and its attendant degradation and sorrow. If you refuse the writer, listen to an Apostle, for your interests, highest and lowest, are bound up together in the exercise of that glorious Christian principle he so beautifully expressed: "It is good neither to eat flesh nor to drink wine, nor anything whereby thy brother stumbleth or is offended, or is made weak."

QUESTIONS FOR EXAMINATION.

THE numbers following the questions indicate the pages where the answers may be gathered. The first numbers apply to pages within the chapter specified, are the most important, and are in heavier type. The lighter figures apply to pages giving contributory information.

SECTION I.—SCIENCE FOR TOTAL ABSTAINERS.

CHAPTER I.—THE AIR WE BREATHE.

1. What do you know of the use of the air? **10.**

2. Explain why we do not see the blueness of the air unless we look at distant objects. **11.**

3. What advantages arise from air and water both being colourless? **12.**

4. State the uses of the wind. **13.**

5. In what relation do the weights of water and air stand? Does this relation ever vary? **14.**

6. Using a two-foot rule, how could you find the weight of the air in a room? **14.**

7. What weight of water would a cistern hold if 3 feet long, 2 feet wide, and 2 feet deep? **14.**

8. Describe an experiment that shows that air expands when made warm. **15.**

9. Why does air ascend when made warm? **15.**

10. While gas is escaping in a room, where does the larger amount of it collect? Give your reason. **16**, 44.

11. Why does a fire in a room cause ventilation? **15.**

12. Why must a narrow-necked bottle be filled slowly, and why does it gurgle in emptying? **16.**

13. Give a simple experiment to show that air resists pressure. **16.**

14. Why is it necessary that a diver should have an uninterrupted supply of air? **17.**

CHAPTER II.—The Chemistry of the Air and Combustion.

15. Of what gases does the air consist? **18.**

16. With what does the gas hydrogen unite in burning, and what is the result? **20, 23.**

17. How can we readily show that paper, bread, &c., contain carbon? **20**, 192.

18. Give one or two simple experiments proving that a burning candle forms water. **21.**

19. Why does paper or glass held over and upon a candle-flame cause soot (carbon) to be deposited? **22.**

20. What gas is produced by burning carbon, and give some of its properties? **22**, 35, 42, 175, 193.

21. Why does a taper burn so vigorously in oxygen gas? **23.**

22. Would any troubles arise if our air were all oxygen? **23.**

23. Give a simple way of preparing oxygen. **23.**

24. Does any change occur within us that may be compared to the burning of a candle? **26**, 170, 175.

25. Show from the properties of carbonic acid gas the great need of complete ventilation. **26**, 35, 185.

26. What effect have intoxicating drinks in relation to oxygen and carbonic acid gas? **26**, 174, 185.

CHAPTER III.—Chemistry of Water.

27. Give some curious changes caused by chemical combustion. **27.**

28. State what you know of the number and rarity, or otherwise of the chemical elements. **28.**

29. Illustrate the difference between a chemical union and mere mixing. **30.**

30. What is the composition of water, and explain how it is constantly being produced? **31.**

31. What is stated of the size and qualities of atoms? **29.**

32. Hydrogen is the lightest known body, what is said of its weight? **32.**

33. Why are gases much lighter than solids or liquids? **32.**

34. What is meant by a molecule of hydrogen and a molecule of water? Write both as the chemist does. **33.**

35. Give an experiment showing how a candle in burning needs constantly fresh supplies of air? **34.**

36. If a candle is burnt under a tumbler does it unite with all the contained oxygen? If not, why not? **35.**

37. Why can no life exist without water? **36.**

38. What is said of water as a part of intoxicating drinks? **36,** 83, 92, 113, 128.

CHAPTER IV.—The Chemistry of Carbonic Acid Gas.

39. How is lime water prepared? **37.**

40. Why does lime water require careful corking? **38.**

41. How is lime water changed by CO_2? **39,** 175.

42. Name a ready way for the chemist to make CO_2. **40.**

43. Why does sherbet effervesce when wetted? **40.**

44. Describe some experiments made with CO_2 and a taper. **41,** 175.

45. Why is it often dangerous to enter a brewer's vat? **43,** 81, 84, 104.

46. How should those be protected who are forced to enter air containing much CO_2? **43.**

47. How may the condition of a vat or well be tested by a candle? **43.**

48. Why does not the CO_2 of our breath collect near the floor? **44.**

49. Why are the products of burning heavier than the substances burnt? **44.**

50. What substances, and what amount of those substances, would be produced by burning 1 lb. tallow and 1 lb. paraffin? **44.**

51. How may corks be prepared for use with strong acids? **41.**

CHAPTER V.—How the Air is Kept Pure.

52. Mention some sources whence noxious vapours are poured into the air. **46.**

53. What elements are found in vegetable substances? **47.**

54. How is charcoal made? **47.**

55. How do plants obtain their carbon? **48, 53.**

56. Describe a leaf with its stomata, explaining the use of the latter. **49.**

57. Explain why the air is cool in the shade of a forest. **50.**

58. Give and explain Stephenson's answer to the question, "What drives your train?" **51.**

59. Show that all artificial heat comes from the sun. **51.**

60. What do you know of the heat caused by decay? **52,** 176.

61. How is heat obtained by us from our food? **52,** 170, 178, 182.

62. What is the result of alcohol delaying the combustion of food? **52,** 176.

63. Trace carbon from animals through vegetables to animals again. **53.**

CHAPTER VI.—Plants as Food Makers.

64. Why are all combustible substances necessarily vegetable in origin? **54.**

65. In what sense are all people vegetarians? **56.**

66. Why is a parsnip not fit for food at the end of its second season's growth? **57.**

67. Describe the manner in which the starch is stored in a potato. **58.**

68. In what part of plants does growth really occur? Give reasons for the answer. **58.**

69. Explain that fruits have passed through their own stalks. **59.**

70. Explain how starch is formed in plants. **59.**

71. How and for why is starch changed in plants? **60.**

72. Why would starch be unsuited to storing in plants? **61.**

73. Describe the embryo in the wheat grain. **62.**

74. What changes occur during the early growth of the wheat grain? **63.**

75. Give some account of the wonders of plant growth, and trace these wonders to their origin. **64.**

Section II.—Intoxicating Drinks.

CHAPTER VII.—Fermentation.

76. What is the origin of "intoxicating"? **66.**

77. How did the expression "spirits of wine" originate? **67.**

78. Alcohol is nowhere found in living plants and animals; by what then is it brought into existence? **67, 68, 75,** 80, 84, 85, 91, 104, 124.

79. How is the souring of milk caused? **69.**

80. Why does the scalding of milk, temporarily preserve it from souring? **71.**

81. State what you know of the size, movements, and method of increase of bacterium lactis. **69.**

82. What curious discovery did Pasteur make respecting milk? **70.**

83. What is the cause of fermentation or souring of beef tea? **72.**

84. Explain why tinned meats remain good until opened. **73.**

85. Give an account of the mildewing of leather, bread, or glue. **74.**

86. Give a reason, relating to germs or spores, for keeping our homes clean, dry, and well ventilated. **75.**

87. Explain how mildew in one place tends to start mildew in another. **75.**

88. Are mildew germs capable of producing alcohol? **75,** 101, 109.

CHAPTER VIII.—Wines in General.

89. What should be remembered respecting the word wine, as used in the Bible, &c.? **77.**

90. Give some account of the growth of the vine. **78.**

91. What claim, as to variety in wine, has been made? **78.**

92. State the constituents of grapes; pointing out particularly the foods they contain. **79,** 92.

93. How is fermentation started in the *must?* **80,** 88.

94. Why do grapes not ferment until broken? **80,** 85, 88.

95. What changes occur as fermentation progresses? **80, 84,** 92.

96. What ground is there for believing that alcohol is one of the refuse matters produced by the ferment? **81.**

97. How does the heating of the must, during fermentation, prove loss of food? **81**, 103.

98. What gives a frothy crust to the must? **81**, 90.

99. Why is it necessary, if wine is to be made, that the air should be kept from the must? **81**, 90, 104.

100. What are wine lees? **82**.

101. What is the cause of bouquet in wine? **82**, 92.

102. What causes some wines to be still, while others are sparkling? **82**.

103. Why are wine ferments especially abundant in wine countries? **83**, 75.

104. Give the result of splitting up the molecule of grape sugar by fermentation. Express this change in chemical symbols if you can. **80**, **84**, 90, 95, 104, 124.

105. What amount of alcohol is produced from 180 lbs. of sugar? (Explain the reason by the atomic weights.) **84**.

106. Why are British wines often very intoxicating? **85**.

107. How is decaying rhubarb used in wine-making? **85**.

108. Valuable sugar becomes poisonous alcohol; give illustrations from a candle and dinner-salt quite as curious and remarkable. **86**.

CHAPTER IX.—Port Wine.

109. Describe the port wine country. **87**.

110. Describe the lagar in which the grapes are fermented. **88**.

111. In what way is the treading performed? **88**.

112. What is meant by "*the hat*," and how does it prevent the formation of vinegar? **90**.

113. What is meant by "dry port"? **90**.

114. How is "fruity" wine produced? **91**.

115. What is meant by fortified wine? **91**.

116. Why cannot natural or unfortified wine contain more than 13½ per cent. alcohol? **91**.

117. Why is wine fortified? **91**.

118. Why are the grapes trodden instead of pressed? **92.**

119. Why is port wine only slightly nourishing? Make an estimate of the nutrition in a gallon of it. **92, 93.**

120. What becomes of the albumen of the grape? **92,** 80, 99.

121. Why is port wine red or purple? **93.**

122. What is the origin of tannin in port wine? **93.**

123. What do you know of imitation port wine? **94.**

124. Give the substance of the opinion of some medical men of repute respecting port wine. **94.**

CHAPTER X.—Ale and Beer.

125. Describe the process of malting. **96,** 123.

126. Why is barley, as such, unsuitable to the purposes of the brewer? **95.**

127. What is the real object of malting? **97.**

128. State what you know of diastase? **97, 99,** 123, 138.

129. How do malt and barley grains differ in form? State the cause of this difference. **97,** 62.

130. What variations are produced in malt by the manner of its drying, and how are these varieties used? **98.**

131. Why must the beer be kept as free from albumen as possible? **98, 100,** 113.

132. Why are the sprits removed? **98.**

133. What is the object of mashing? **99,** 124.

134. In what way is the albumen that dissolves out in mashing used up? **99,** 80, 92.

135. Why is the water of the river Trent particularly suited to brewing, so that Burton-on-Trent has become a city of brewers? **100.**

136. What are the constituents and qualities of sweet wort? **101,** 111, 124.

137. Why is sweet wort not left to ferment of itself? **101.**

138. Describe the yeast plant and its manner of growth? **102,** 80.

139. How may small quantities of yeast be cultivated? Why should it not be grown in a corked bottle? **103.**

140. Describe how CO_2 may be collected from fermenting sugar. **104.**

141. Why are spirit-makers buyers instead of producers of yeast? **106.**

142. Summarise the changes in the sweet wort during fermentation. **106,** 80, 92, 99, 124.

CHAPTER XI.—Brewers' Exhibition.

143. Explain how starch can be changed into sugar by the action of sulphuric acid. **110.**

144. Describe "The Converter." **111.**

145. Why is the wort from "The Converter" treated with powdered chalk? **111.**

146. What is Saccharum, and of what use is it in brewing? **112,** 80, 92, 99.

147. State as accurately as you can the constituents of Bass's pale ale, and point out the foods. **113.**

148. Compare ale with porter, and mark wherein the chief difference lies. **114.**

149. Compare ale and bread as to value for money cost. **115.**

150. How is the presence of glycerine and succinic acid in ale to be explained? **115,** 84.

151. Explain the conversion of ale into vinegar, if air be allowed free access to it. **116,** 82, 104.

152. Name the most common adulterations of beer. **116.**

153. Do you think adulteration has much to do with the mischief caused by ale and beer? State your reason. **117.**

CHAPTER XII.—Spirits.

154. Why are spirits so called, and what is their character? **118.**

155. What is distillation? **118.**

156. Name a simple way of preparing distilled water. **119.**

157. At what temperatures do water, alcohol, and a mixture of equal measures of each boil? **120.**

158. If equal measures of alcohol and water be heated, why does more of the former pass off in vapour? **120.**

159. Describe the simple distillation of a few ounces of port wine. **121.**

160. What is the result of distilling port wine? **121.**

161. How is French brandy made? **122.**

162. Describe an ordinary still (giving a sketch). **123.**

163. If the process of malting be applied to other grains than barley, what alterations are made in them? **123,** 97.

164. How is the sweet wort for Scotch or Irish whisky prepared? **124.**

165. How is "wash" made for spirit distilling? **124.**

166. What is fusel oil? **125.**

167. What is rectification and its objects? **125.**

168. In what way can spirit be obtained from potatoes, and why is it particularly destructive to the constitution? **126.**

169. Explain the mystery of making spirit from rags, paper, or woody fibre. **126,** 110.

170. What is "silent spirit"? **126.**

171. Give some account of the inferior kinds of gin, brandy, whisky, and rum.

172. What is meant by "proof spirit" and "above" and "below proof"? **128.**

173. Give some figures respecting the size of one of the London spirit stills. **129.**

174. Is fermented bread alcoholic? If not, why not? **130.**

SECTION III.—ALCOHOL AND THE BODY.

CHAPTER XIII.—ALCOHOL AND DIGESTION.

175. In studying the action of intoxicating drinks on the body, why is it enough to study the action of alcohol? **131,** 114, 128.

176. Give some proof that the greater weight of our food is required to make up waste. **132.**

177. Why does the body shrink and become constantly lighter if food is withheld? **133.**

178. Name the three kinds of loss which are constant during life. **133.**

179. How can we prove the body's loss of water? **133.**

180. Why cannot alcohol repair tissue? **134.**

181. Why cannot alcohol replace water? **135.**

182. Express in a few words the steps by which foods become converted into our very material? **135.**

183. How can the gluten of flour be separated from the starch? **135.**

184. Show that bread and water form, although a poor, still a complete diet. **136.**

185. Describe the salivary glands, and state their position. **136.**

186. Explain the main use of saliva (and compare it with diastase). **137, 138,** 97, 99, 124.

187. What is peculiar of the saliva of babies? (What lesson do we learn from this fact?) **138.**

188. Describe a simple experiment which proves that alcohol hinders the saliva in its important duty. **139.**

189. What is maltine, and what is its medical use? **139.**

190. Give a simple experiment with growing grain which proves that alcohol injures diastase. **140.**

191. What lesson do we get from animals with regard to mastication (chewing)? **141.**

CHAPTER XIV.—Stomach Digestion and Alcohol.

192. How are food and drink carried to the stomach? (Show by an observation on the horse that they are really carried.) **142.**

193. Give some description of the glands which secrete gastric juice. **143.**

194. What occurs when food enters a previously empty stomach? **143,** 160.

195. What is the general duty of gastric juice? **144.**

196. How is it possible that white of egg, cheese, gelatine, &c., can be made into nearly identical bodies in the stomach? **144.**

197. When stomach digestion is complete what still remains to be done? **145,** 153.

198. In what manner did Alexis St. Martin become useful in the study of the process of digestion? **145,** 160.

199. How did Dr. Beaumont prove that alcohol hindered digestion of meats? **146.**

200. What lesson with regard to digestion do we learn from alcohol preserving nitrogenous matters from change? **146.**

201. In what way would strong alcohol act on a steak? **147.**

202. The hardening action of alcohol is due to two causes. Name them. **147.**

203. What is the pylorus, and what is its office? **148,** 145, 164.

204. What are peptones? **148.**

205. What effect has alcohol on peptones by which it reverses the work of digestion? **148.**

206. What fact alone makes digestion possible when strong alcoholic drinks are taken? **149.**

207. What experiment in artificial digestion shows how alcohol delays the work of the stomach? **150.**

208. What effects upon the coats of the stomach have moderate quantities of ale? **150.**

209. Describe the effect of hard drinking upon the glands of the stomach. **151.**

210. What condition of stomach is associated with delirium tremens? **151.**

211. What are the characteristics of delirium tremens? **152.**

212. Under what conditions is alcohol least harmful? **152.**

CHAPTER XV.—Biliary and Pancreatic Digestion and Alcohol.

213. Distinguish between fat of meat and dripping. **153.**

214. What is the office of the pancreatic juice? **155.**

215. Whence comes the bile and what is its use? **155.**

216. In what form does butter exist in milk? **155.**

217. Describe the structure of the villi of the bowel. **156.**

218. How are the results of digestion, when gathered up by the villi, poured into the blood? **157,** 171.

219. Why is the damage of alcohol to the liver specially severe? **157.**

220. Quote some statistics showing the frequency of liver disease amongst drinkers. **157.**

221. State how the liver alters the sugar which is carried from the stomach into the blood. **158.**

222. Explain the effect of intoxicating drinks on the liver secretion. **158,** 226.

223. What is meant by gin drinkers' liver? **159.**

224. Give as nearly as you can some remarks of Dr. Beaumont, which show that by alcohol great injury may be done to the stomach without causing pain. **160.**

225. Explain why alcohol at first causes an increase of gastric juice. **161.**

226. What is meant by the stomach putting on a tolerance? **161**, 228.

227. Explain a tolerance in relation to the hands and work. **161**, 228.

228. When people who have freely taken intoxicants begin to abstain, why do they often feel discomfort? **162**, 228.

229. How can converts to total abstinence be assisted if discomfort be felt at first? **162.**

230. What is the action of intoxicants upon the pylorus? **163.**

231. How can indigestion occasion pain, and does this pain serve any useful purpose? **163.**

232. Why is alcohol sometimes falsely credited with curing indigestion? **164.**

233. What is the action of alcohol as a narcotic upon the nerves of sensation of the stomach? **163.**

CHAPTER XVI.—Alcohol and the Blood.

234. How is the carrying of food matters to the different parts of the body accomplished? **165.**

235. Every tissue needs blood; give the reason. **165**, 133.

236. Describe briefly the heart and the course of the circulation. **166.**

237. Why is it necessary for the blood to carry oxygen to all the tissues? **165.**

238. In what way does the blood pass from the arteries to the veins? **167.**

239. Give some account of the delicacy, closeness, and multitude of the capillaries. **167.**

240. What effect has alcohol in the blood on the work carried on by the capillaries? **168**, 52, 176.

241. Give some account of the blood corpuscles; stating their size, shape, and number. **169.**

242. What division of duty occurs between the corpuscles and the plasma? **170.**

243. What is the total surface of the air-cells of the lungs of a man? **172.**

244. What explanation can be given of the smallness and flatness of the blood corpuscles? **173.**

245. What is the total area of the blood corpuscles of a man? Why is it so immense? **173.**

246. What experiments with blood show that alcohol thwarts nature in her effort to secure oxygen? **174.**

247. Alcohol shrinks the corpuscles. Explain why this is a damage, when it has been shown that the smallness of the corpuscles is a benefit. **174.**

248. In what way does alcohol affect the appearance and character of the blood and flesh? **174.**

249. Prove by simple experiment that the expired air contains CO_2. **175.**

250. What two opposite results with regard to CO_2 are produced by food and by alcohol when consumed? **176.**

251. Show how alcohol reduces vitality and nutrition. **176,** 224.

252. Show that it is a simple matter of proportion to prove that alcohol reduces the amount of heat that can be produced and the amount of work that can be accomplished. **177.**

253. Show why athletes are generally abstainers, and explain the effect of alcohol on thought. **177,** 133, 203.

254. In what way does alcohol tend to bring our blood into the condition of that of the reptile? **178.**

CHAPTER XVII.—Alcohol and the Blood—*Continued.*

255. Give some account of the temperature of the blood and that of the body generally. **179.**

256. How does the thermometer assist the doctor? **180.**

257. Give the temperature of the stomach, and state if digestion is influenced by temperature. **180,** 149.

258. Describe the perspiratory glands, and explain how they act as regulators of temperature. **181.**

259. How are combustive foods made to supply heat as it may be needed to keep up the health temperature? **182,** 177.

260. How can the feat of remaining in an oven during the cooking of a dinner be explained? **182.**

261. How does alcohol lessen our power of heat production? **183.**

262. When alcohol is taken, what fluctuations in temperature are observed? **183,** 212.

263. Does alcohol assist in bearing great heat? (Give reasons for your answer.) **183.**

264. What drink is found most helpful to those working hard in high temperatures? **184.**

265. Give the substance of Sir Charles Napier's advice to the Army at Calcutta. **184.**

266. Why does less oxygen in the corpuscles lead to increased CO_2 in the plasma of the blood? **185.**

267. Why do ales cause drowsiness? **185.**

268. Why does alcohol act on the body like the impure air of an ill-ventilated room? **185.**

269. Explain the use of blood-fibrin. **186.**

270. What influence has alcohol on the cure of wounds? Give and explain the experience of savage races. **186.**

271. How do brewers' draymen frequently suffer from blood changes caused by beer drinking? **187.**

272. How does increased water and decreased fibrin in the blood tend to make life uncertain? **187.**

273. Explain why intoxicants often cause bulkiness of body. **188.**

274. Explain fatty degeneration of muscle, and show why alcohol causes it. **189,** 225.

275. How is alcohol disposed of in the body? **187,** 189.

276. How does alcohol influence the body so as to shorten the term of life? **190,** 227, 234, 247.

277. Give the consequences of the fatty degeneration of the blood? **190.**

278. Give an experiment showing that oxidation produces heat. **191.**

279. How may carbon in ordinary food be demonstrated? **192.**

CHAPTER XVIII.—Alcohol and the Brain and Nerves.

280. Give a short account of the brain and nerves. **196.**

281. Describe and explain the appearance of a section of a nerve trunk. **196.**

282. If a part of the body has been pinched, how can we by a sensation in the brain determine what part? **197.**

283. Explain the process of bending the arm at the elbow. How is it again straightened? **198.**

284. Give one or two illustrations of the accuracy with which we can control our muscles. **196.**

285. Give the weight of the adult brain and the amount of blood it receives. **200.**

286. How do small doses of alcohol damage the nerves and through them the muscles? **201.**

287. Show why alcohol by injuring nerve destroys the accuracy of muscle. **201.**

288. Explain why total abstainers are generally the best athletes, marksmen, &c. **202.**

289. Narrate the capabilities and testimony of Ira Paine. **203.**

290. Tell of Dr. Carver's marksmanship, and relate his statement respecting intoxicants. **204.**

291. State Dr. Richardson's experiment on the muscle of a frog. **204.**

292. What makes the beginning of drinking so dangerous? **205.**

293. Explain the function of the spinal cord. **206.**

294. What are the indications as intoxication advances that the spinal cord has lost its power? **206.**

295. What follows the intoxication of the brain proper so that judgment and will are dethroned? **206.**

296. Why is dead drunkenness not commonly fatal? **207.**

297. Is the idea that alcohol acts in two distinct ways well founded? **207.**

CHAPTER XIX.—Alcohol and the Brain and Nerves—*Continued.*

298. Enumerate some voluntary and some involuntary movements. **208.**

299. Describe the walls of the arteries and give reasons for their strength. **209.**

300. Describe the minute arteries and explain how they regulate the circulation. **209.**

301. How do the vaso motor nerves produce paleness through fright? **209.**

302. Explain the general blushing or arterial engorgement caused by alcohol. **210, 217.**

303. Describe and explain an experiment with alcohol and the foot of a frog. **211.**

304. Describe a personal experiment to show the effect of alcohol on the vaso motor nerves. **211.**

305. From what two causes does alcohol produce decrease of temperature. **212,** 183.

306. Explain how loss of heat at the skin cools the interior of the body. **212.**

307. Give an explanation of the common mistake that alcohol warms when it really cools, taking a hot pudding as an illustration. **212.**

308. What is the cause of "gooseflesh," and why is it a natural safeguard? **213.**

309. Why does alcohol prevent "gooseflesh," and why is its action specially injurious? **215.**

310. In what way can birds partly protect themselves from severe cold? **215.**

311. Explain the meaning of the red or purplish colour of the face of some drinkers. **216,** 174.

312. Why do intoxicants so often disfigure the nose? **216.**

313. Why do intoxicating drinks predispose to inflammatory attacks? **216,** 226.

314. Describe the effect of habitual drinking upon the brain. **217.**

315. How and to what extent does alcohol induce lunacy? **218,** 238.

CHAPTER XX.—Alcohol and the Vital Organs.

316. Give illustrations showing the variation in the heart's rate according to effort. **220,** 182.

317. Give the results of the experiments of Dr. Parkes on the effect of alcohol on the pulse. **221.**

318. What is the main cause of the quickening of the pulse under alcohol? Illustrate the argument by reference to a fire engine. **221.**

319. What calculation will prove that the heart's power is principally expended in driving the blood through the *small* vessels? **222.**

320. Explain the grounds for concluding that the heart's output of energy is less under alcohol, although its beating is quicker. **223.**

321. Why is it almost certain that the rate of the blood is reduced although the heart is quickened? **223.**

322. Why does the heart beat more slowly than the health rate as the effect of alcohol passes off? **224.**

323. Why is the heart peculiarly likely to have fatty degeneration induced by alcohol? **225,** 189.

324. What unhealthy state does alcohol produce in the blood vessels? **225**, 187.

325. From the known effects of small quantities of CO_2, explain the fact proved by statistics that moderate drinking shortens life. **225**, 190, 248.

326. Explain how alcohol both injures and hinders the lungs. **226.**

327. Alcohol often causes fatty degeneration of the liver; state the appearance and effect of this change. **226.**

328. Show how alcohol destroys life more frequently than a table of the causes of death would show. **227.**

329. Show that the effect of alcohol exactly resembles that of approaching decay from age. **227**, 185.

330. Explain why indulgence conduces to craving for drink. **228**, 161.

331. Show why alcohol induces a belief that it is necessary (using a head wind as an illustration). **228**, 161.

332. Explain how alcohol may be useful as a drug. **229**, 252.

333. Why is alcohol sometimes used in failure of the heart (and show how it is at best but a necessary evil)? **230.**

334. Give the erroneous and true view of a stimulant. **231.**

335. Illustrate that nature possesses certain curious powers of self-cure. **231**, 168, 176.

336. Explain from the self-curative powers of nature why taking narcotics often produces excitement. **232.**

337. Expose the fallacy that people are kept up by alcohol. **233**, 168, 174, 176.

SECTION IV.—ALCOHOL AND THE NATION.

CHAPTER XXI.—WASTE AND WOE.

338. Endeavour to show by an illustration the enormous money cost of intoxicating drinks. **235.**

339. Illustrate the waste of corn in Great Britain in manufacturing intoxicants. **237.**

340. Relate the evidence of Mr. B. Whitworth which states the money loss in his own firm through drinking amongst the men. **239.**

341. Give some facts and opinions respecting crime and drink. **240.**

342. Show the bad effect of intoxicants upon the conduct of soldiers. **241.**

343. How has Belgium suffered through relaxing the licensing laws? **242.**

344. What results have followed the experiment of banishing the public-house? **242.**

345. Explain if you can the cruelty and fury of those in a drunken condition. **243.**

346. Show that drunkenness is not always voluntary. **244.**

347. Where does freedom lie—on the side of total abstinence or intemperance? **244.**

348. What is your opinion of the saying, in reference to the drunkard: "He is no one's enemy but his own"? **244.**

349. Seeing the woe and sin caused by drink, what does love to our neighbour seem to dictate? **245,** 255.

CHAPTER XXII.—Drink and Death.

350. What observation has led many life assurance offices to divide the assured into two sections? **248.**

351. What remarkable facts have become evident through the separation of abstainers from non-abstainers by life assurance offices? **248.**

352. What class of business do many life assurance companies refuse, and on what ground? **249.**

353. What is remarkable of the "comparative mortality" table issued by the Registrar-General? **250.**

354. Compare the death rate and sick rate of the Rechabites and Oddfellows. **251.**

355. How can the difference in health and length of life between the Rechabites and Oddfellows be explained? **252.**

356. What has been the practice, and the result of the practice, in the Temperance Hospital? **252.**

357. What estimate has been made with regard to mortality from drink by Dr. Norman Kerr? **252.**

358. Alcohol shortens life, does it therefore diminish wealth? Explain your answer. **253.**

359. Give some estimate of the total cost of losses from intoxicating drinks, putting each item under a stated head. **254**, 235, 245.

360. Give the reasons why you are or why you are not a total abstainer? **255**, 245.

INDEX.

A

B

C

D

H

I—J

K

L

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